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SYMPOSIUM ON STATISTICS OF CROP PRODUCTION IN INDIA

(AT UDAIPUR)

From 11 *a m to* 1 *p m* ; 3 *p m to* 3-30 *p m* , 3-45 *p m to* 4-15 *p m* , 5-15 *p m to* 6 00 *p m on the* 20*th December* 1945

(IN THE CHAIR SIR C V RAMAN)

DR P. V. SUKHATME, opening the symposium, said that statistics of crop production depended on two factors:

(*a*) the area under the crop, and

(*b*) the average yield per acre

Statistics of acreage under the different crops were known with a high degree of accuracy for the temporarily settled parts of British India, but the position in the permanently-settled parts and in the States was unsatisfactory There was an elaborate revenue agency in the temporarily-settled parts. Every patwari was required to make a field to field inspection of the villages under his charge in the ordinary course of his duties and there was also adequate senior staff to supervise his work In the permanently-settled parts, however, there was no suitable revenue organisation The village official was only a *chowkidar*, who was mainly a police official, was ill-paid and illiterate as compared with the patwari in the temporarily-settled areas, and therefore, ill-equipped to record area under crop by field to field inspection. The procedure of ascertaining acreage in the permanently-settled parts was to ascertain the relation which the area under the crop in any year bore to the normal acreage of that crop This was done by each subdivisional officer who passed on the estimates to the district officer The latter modified the estimates so received in the light of his personal experience and passed on the modified estimate to the Director of Agriculture That was the reason why acreage estimates were not accurate The position was even worse in the States as no acreage statistics of any sort were maintained for nearly 2/5 of the area covered by them

The method of random sampling was suggested as an alternative for estimating the acreage in the permanently-settled Provinces and States where revenue organization on the model of the patwari agency in the temporarily-settled parts, did not exist. The method consisted in inspecting randomly selected sample areas in place of each and every field in the province. The possibilities of the method were explored for a number of years, both in Bengal and Bihar, but the results did not appear to be encouraging As an instance he told that results relating to the random sample survey carried out in 1943-44 in Bihar showed that the margin of error of the acreage estimates even for such large area as a district was so high as to make the estimates almost valueless for administrative decisions The margin of error was particularly large for crops which occupied relatively smaller area Such were the results even when the scale of sampling covered every village in the province Since acreage estimates formed the basis for the whole range of agricultural statistics, it was desirable that this basis should be as complete as possible, and, in any case, reasonably accurate figures should be available for all crops and for territorial units of the size of the district He was glad that the Bengal Famine Commission, who examined the question in considerable detail, were of the same view They wrote 'If full and detailed information as regards acreage under all crops is the objective, as it certainly should be, such information can only be obtained by means of complete field to field enumeration and not by the random sampling method' Their conclusion deserves serious attention on the part of all interested in the improvement of agricultural statistics Complete field to field enumeration by well-trained village agency was the only method of bringing about lasting improvement in the acreage statistics As such he said that in the permanently-settled parts this agency should be immediately established and strengthened on the model existing in the temporarily-settled parts. He was glad that Orissa had already appointed an agency to carry out field to field enumeration He was also glad that Bihar, after having given a trial to the random sampling method, gave it up as unsatisfactory and had now taken to complete enumeration by the method analogous to that in the temporarily-settled Provinces. He hoped that Bengal would follow suit and would set up the necessary organisation for complete enumeration

Turning to the second factor, *viz*, the average yield per acre, he said that under the existing official procedure this was determined by multiplying the normal yield by the condition factor The normal yield was defined as the yield per acre on average soil in a year of average character The condition factor was a subjective estimate of the crop in terms of the normal. The determination of both these factors was largely a matter of guess work, as was apparent from the fact that the average of the condition factor over a series of years was not equal to the corresponding equivalent of the normal The correct approach was to conduct crop-cutting experiments on the principle of random sampling in numbers which were large enough to determine the average yield per acre for the whole province, and, if possible, for each district, The application of this principle involved five considerations —

(1) How to select a random sample of sites for experiments within a stratum.

(2) What is the most practicable way of dividing the province into homogeneous strata

(3) How many sample plots should be chosen for experiments

(4) How should the plots be distributed among the different strata

(5) What should be the shape and size of sample plot for experiments

Random sampling implied an equal chance for every sample plot under a crop to be included in the sample This could be done either by selecting random points and constructing a sample plot at each of these points or by selecting random fields and locating a sample plot in each selected field It was not practicable to locate a selected plot by means of the first method The second method too was not feasible, since it was not practicable to prepare a list of all the fields in advance and select therefrom A practical method of selecting a random sample of fields was to select a sample of groups of fields and then select a sample of individual fields from each selected group Previous investigations especially those of Panse and Kalamkar and his own showed that the most convenient method of selecting a random sample of sites for experiments was to select villages, to select fields in selected villages and to locate a plot in each selected field It was, however, possible that in this method the yield estimates may be biased if yield was associated with the size of a village or a field One could, however, always weigh the plot-yields with the area under the crop in selected fields and villages and obtain corrected yield estimates in case there was any association between the yield and area under the crop in a field or village His own results showed that no correction was required in practice

The object of dividing the province into homogeneous strata was to eliminate the differences in yield between the strata from the sampling error of the mean yield for the province This was known as the method of stratification. It consisted in dividing a province and its districts into zones which were as homogeneous as possible He said that stratification by tahsils was found to be administratively convenient and statistically efficient, but he would leave the implications of this finding to be explained by Dr. Panse, who was to follow him.

The number of experiments to be conducted for estimating the provincial mean yield with a given precision depended upon the magnitude of the variability between villages and the magnitude of variability between fields within villages If 'f' fields were sampled from a village and 'p' plots were sampled in a field and the number of villages sampled from each stratum was in proportion to the area under the crop in the stratum, then the sampling variance of the average estimate of yield for the province was given by

$$V(x) - \frac{V}{n} + \frac{F}{nf} + \frac{P}{nfp},$$

where n is the number of villages in the province selected for experiments and V, F and P denoted the estimates of the true variance between villages within strata, between fields within villages and between plots within fields respectively A glance at the formula showed that for a given number of experiments the sampling error of the estimated yield was the least when experiments were so distributed that one experiment each was conducted in a different village of the stratum Given the values of V, F and P one could determine the number of experiments required for attaining the objectives of crop-cutting experiments There were, however, other considerations which determined the number of experiments and its distribution within a stratum These were (*a*) the staff available, (*b*) the number of days available for harvesting and (*c*) the cost When crop-cutting experiments had to be conducted with the help of the departmental agency, as in India, and the period available for harvesting was limited to about a fortnight, as in the case of wheat, the number of villages that could be allotted to each field staff was limited For, unlike in U S A , and England, travelling from one village to another was difficult in India and took, on an average, a day from one random village to another in a tahsil Again, of all items of cost, travelling between villages was by far the largest item It was, therefore, important that having reached a village, the worker was asked to utilise the day fully These considerations led to a scheme of work which counselled more than one experiment per village Three fields per village and one plot within a field was found to be about the optimum distribution He said that he had calculated tables from which the number of villages required for estimating the mean yield with a given precision could be readily determined

The size of plot to be selected for experiments was a matter of considerable controversy In countries like U S A and England the plot size adopted was very small, of the order 1/3,000th of an acre Even in India workers in Bengal and Bihar adopted small size plot of about the same order These plots were marked with the help of rigid or semi-rigid frames In his surveys he was, however, using a much larger plot size varying from 1/100th to 1/20th of an acre depending upon the tract and the crop. The plots were marked with the help of chains and pegs He had conducted investigations for comparing small size plots as were marked with the help of rigid or semi-rigid frames and were used in Bengal and Bihar with large size plots such as he himself adopted in his surveys The results of these investigations brought out certain interesting facts As an instance, he gave figures for the average yield for each plot size obtained in his investigation in the district of Moradabad (U P) shown in Table I

TABLE I

Irrigated wheat

Shape of plot	Size of plot in sq ft	No of plots	Average yield	Percentage over estimation	Standard error of the average yield
Equilateral triangle					
Side 33′	471 55	78	10 10		0 94
Side 16½′	117 89*	78	10 58	4 8	0 99
Side 8′	29 47*	78	11 69	15 7	1 23
Radius 3′	28 27	117	11 60	14 9	1 10
Radius 2′	12 57	117	14 38	42 4	1 14

Unirrigated wheat

f plot	No of plots	Average yield in md per acre	Percentage over estimation	Standard error of the average yield
Equilateral [illegible]gle				
Side 33′	107	6 55		0 74
Side 16½′	107	7 27	11 0	0 82
Side 8¼′	107	8 08	23 4	0 83
Radius 3′	162	7 52	14 8	0 78
Radius 2′	161	9 33	42 4	1 03

* These two triangles were obtained by subdividing the first triangle (side 33′) into 3 strips by means of lines parallel to the base at distance of 16½′ and 8¼′ from the vertex along the side

He said that a glance at the table showed that smaller plots gave over-estimates The degree of over-estimation decreased as the plot size increased, but even as large a plot as 118 sq ft was not free from bias The results were consistent both for irrigated and unirrigated wheat and for each tehsil in which experiments were carried out The reults ewere conclusive in showing that the use of small size plots such as were adopted in Bengal and Bihar, in the unevenly sown crops in India and possibly also U S A and England, was attended with risk and, in all probability, led to serious over-estimation of the yield per acre.

The probable reason for over-estimation in plots of small size was the human tendency to include too many border plants inside the plot. In the case of small plots the number of plants on the border formed an appreciable proportion of the total number of plants inside the plot The estimate of yield was consequently more influenced by the contribution of border plants in the case of small than large size plots A plant consisted of several tillers with a fairly large width at the base on the ground The workers, therefore, naturally experienced difficulty in deciding whether to include the border bunches inside the plot, to exclude them or to divide them The results indicated a tendency to include the bunch as a whole inside the sample area Naturally with increase in the size of the sample plot and the consequent increase in the harvested sample produce, the degree of over-estimation resulting from the inclusion of border plants also diminished He had also carried out investigations for comparing large size plot with the field as a whole and gave figures to show that the estimate of the average yield as obtained from the large size plot and from the field as a whole agreed within the margin of their sampling errors

Smaller plots also involved more sampling than larger plots As an instance he presented Table II

TABLE II

Size of plots	33′ Triangle			8¼′ Triangle			2′ Circle		
No of plot in a field	1	2	3	1	2	3	1	2	3
No of fields in a village									
IRRIGATED—									
1	88	74	70	163	137	128	180	138	124
2	54	50	48	90	81	78	86	73	68
3	47	45	44	75	70	68	68	59	57
UNIRRIGATED—									
1	169	146	139	233	183	166	393	322	299
2	111	103	103	149	133	127	243	220	212
3	99	95	93	133	[illegible]	119	213	199	194

This table showed that for a given number of fields in a village and a given number of plots in a field, the number of villages required for estimating the mean yield with a given precision increased as the plot size decreased As an illustration, he said, that in sample surveys on full provincial scale where three fields were sampled in each village and one plot in each field, the table showed that the use of a plot size 12 6 sq. ft in area in place of a triangular plot of area 472 sq ft involved 60 per cent. more sampling for estimating the mean yield with 5 per cent sampling error. In general, the table showed that the use of small size plots in place of the large size plots, which he was adopting, led to a considerable increase in the number of villages to be sampled in order that the yield could be estimated with the same precision. The number of days available for harvesting being limited, the additional sampling of villages needed additional staff. Even assuming that additional villages could be managed by the existing staff, they would involve proportionate increase in the cost of travelling and, therefore, in the total expenditure on survey, unless that additional expenditure on travelling was offset by a decrease in the cost on actual harvesting of the crop

He said that the same table could also be used to answer whether it would not be possible to replace a large size plot by several small size plots by sampling more fields in a village and harvesting more than one plot in a field without increasing the number of villages The general conclusion that emerged from the table was that the number of fields to be sampled when the plot size was small would have to be much larger as compared with the number of fields when the plot-size was large and might well be uneconomic

The use of small size plots also required a precise technique for its location, marking and handling of its produce, and unless the staff was well trained and great care and vigilance were exercised, there was room for committing several errors in experimenting with them When the agency available for crop-cutting experiments consisted of the available departmental staff, as in India, and when further they were expected to carry out this work in the course of their normal duties, it was also important that utmost simplicity was maintained in the technique By far the greatest risk, however, in the use of small size plots was the possibility of getting biased estimates These considerations coupled with the fact that the amount of sampling required for small size plots was excessive, ruled out the possibility of using them in the unevenly sown crops in India, until, at any rate, such time when facilities for transportation and travel from one village to another changed to what they were available in England and America and a suitable portable frame could be devised which guaranteed unbiased character of the yield estimates.

Dr V G Panse said that a clear explanation of the statistical principles underlying the random sampling method for estimating crop yield had already been given by Dr. Sukhatme He, therefore, intended to illustrate their application by describing a large-scale sample survey on cotton in progress in the Central Provinces

It was in Central Provinces and Berar that the present method of conducting crop yield surveys was first developed on cotton Beginning with a small survey confined to Akola District in 1942-43, there had been rapid and extensive developments and now the method was being applied to province-wide yield surveys on various crops. The present cotton survey in Central Provinces embraced the whole of the cotton area in the province which was about 3 million acres and was the largest provincial acreage under this crop. The cotton area was spread over 10 districts covering a geographical area of 27 thousand square miles The object with which the work was taken up was not merely to determine the yield accurately but to do it in such a manner that the method would be acceptable to the administrators both on account of its practicability and the reliability of its results. The aim was to develop a technique which was scientifically sound and feasible in practice and which could be made an annual departmental feature for estimating crop yield It was only when such a technique was incorporated into the administrative routine that a real and lasting contribution would be made to the improvement of Indian Agricultural Statistics.

He then described the organisation of the cotton survey in progress in Central Provinces in the current year. In each district of the province there were 3 to 5 tahsils or taluqas each with an area of 600 to 800 square miles and containing roughly 400 to 500 villages Further in each taluqa there were what were called 3 to 4 Revenue Inspectors' circles. These circles were taken as the strata or subdivision within which random sampling was done Depending upon the cotton acreage of a circle, 2 or 3 villages were selected at random from the list of villages in the circle In each selected village 3 cotton-growing fields were randomly selected from the complete list of fields having this crop in the particular season. This list was prepared by the village patwari. A plot was marked in a random position in the selected field for harvesting The number of experiments, *i e*, the number of villages and fields, and their distribution in the different districts was based on the technical conclusions derived from the previous seasons' surveys and were expected to provide estimates of yield with a certain desired margin of accuracy. Selection of villages was done centrally and detailed instructions for the selection of the fields and for marking and harvesting plots were given to the field staff The Revenue Inspector of the Circle was responsible for marking the plots in the fields selected by the Provincial Officer. The plot size was 1/10th acre which was the standard size adopted in the departmental crop-cutting experiments It was found that there was no gain, either statistical or practical, in plots of a much smaller size and the retention of the plot size with which both Government Officers and cultivators were familiar had a psychological advantage. Plots were harvested by the patwari. All that he had to do was to pick the cotton of the marked area whenever it was ready, record the yield by means of balançe and weights provided, and report the figure to the District Supervisor immediately after each picking. Cotton was different from other crops in respect of harvesting While the harvesting of other crops was finished in a day, in cotton it had to be done in six or seven rounds of pickings, spreading over three or four months and the plot must remain undisturbed on the ground for the whole season. This was another reason why large plots were necessary for cotton The peculiarity in harvesting of cotton had a compensating advantage in that the possibility of supervision was greater than in other crops

In all there were 1,000 field experiments and from the results of previous surveys it could be predicted that the provincial yield per acre would be estimated with a standard error of about 2 5 per cent Explaining the meaning of the standard error, he said that the yield per acre was a sample estimate and the standard error provided a measure by which the true yield was likely to differ from the estimated yield. Consequently, the smaller the standard error, the narrower would be the range within which the true yield would most probably be. It was, therefore, necessary that the experiments should be planned in such a way that the standard error should be as small as possible The precision of the estimated yield depended upon two factors; (1) Stratification or subdivision of the area, and (2) total number of experiments. For instance, with a given number of experiments to be carried out in the province, 1,000 in the present case, these 1,000 experiments could have been randomly scattered over the whole province Instead, the province was subdivided into districts, the district into tahsils, and tahsil into circles. In this way this large tract was first subdivided into a number of comparatively homogeneous strata and experiments separately located randomly within each stratum so that the differences between these subdivisions would not effect the magnitude of the standard error. Stratification would thus be one factor which would help in increasing precision There was, however, a limit to this gain in precision by stratification, and tahsils, he thought, would be that limit. By a further subdivision of tahsils he did not expect any greater increase in accuracy but all the same this subdivision was found desirable for the sake of administrative convenience. Another factor that governed the precision of experiments was their number The larger the number the greater was the precision. It was on these considerations that he had arrived at 335 villages with 3 fields per village as the most suitable specification for conducting crop-cutting experiments on cotton in Central Provinces.

In such surveys the honesty of the field staff and the reliability of the results supplied by them was always a disturbing consideration to the mind Attempts had been made to overcome this difficulty by arranging that the experimental work was done by two or more parties of investigators moving independently in the same area, thereby providing a check on one another's work. Such arrangement, in his opinion, would not serve the purpose of checking the honesty of the field staff and would not also be practicable as it could not fit in with the departmental administrative machinery. The only check which he considered feasible was to devise adequate technical supervision of the field work and minimise the scope for dishonest work. In the present instance, the field staff had no hand in the selection of experimental plots and all that they were concerned with was proper harvesting and correct weighment of the produce, but here again a check was provided by insisting that the results of harvesting should be reported to the District Supervisor on the very date of harvest

As regards the controversy of the small and large plots to which Dr. Sukhatme had referred, he said that in respect of cotton the question of small plots did not arise. The plot had to be on the ground for a number of months and moreover as only a fraction of the crop was harvested at each picking, the plot had necessarily to be a big one Even otherwise, the question of plot size was a minor one and should not be allowed to assume proportions when the present progress would be in danger of being held up The main objective should be to insist on the fundamentals of a scientific method and demonstrate its practicability to the administrators and this required that only such modifications should be introduced in current methods as were essential The present problem is, " Can we persuade provincial administrations to take up the scientific method of crop estimation as an annual routine immediately ? " On the success in achieving this depended the real contribution of their efforts to the improvement of Indian Agricultural Statistics There would be plenty of time later to consider modifications and further improvements of details

Mr. K. Kishen said that he would illustrate the application of the statistical principles to the estimation of wheat by describing the results of the two crop-estimating surveys on wheat conducted in the United Provinces during 1943-44 and 1944-45 under the technical direction of Dr. Sukhatme. During the 1943-44 *Rabi* season, the survey was carried out in 45 out of the 48 districts of the United Provinces, leaving out the hilly districts of Naini Tal, Almora and Garwal. The geographical area covered was 92,000 square miles The estimated expenditure on the survey (including the expenditure on statistical work) was Rs. 53,000. During the 1944-45 *Rabi* season, one more district, *viz*, Naini Tal (Plains portion) was added to the 45 districts selected in the previous year and the survey was carried out in these 46 districts. The geographical area covered by the survey increased to 95,000 square miles and the estimated expenditure on the survey was Rs. 55,000. In 1943–44, 1,160 villages representing approximately 1·5 per cent. of the total number of villages in the province, were selected for the experiments. In 1944–45, 1,074 villages, representing about 1 per cent. of the total number of villages were selected. In both the seasons, the plan of sampling was similar. The total number of villages selected were divided roughly in proportion to the areas under wheat in the different tahsils. In each tahsil, the field work was usually done by one Junior Supervisor Qanungo, but in tahsils where the number of villages was more than 7, two Supervisor Qanungos were put in charge of the work. The entire field work was so organized that no Supervisor Qanungo was required to carry out the experiments in more than 7 villages The villages within a tahsil were selected at random with the help of printed random numbers to give equal chance to each village to be included in the list of selected villages. Within a selected village, 3 fields were chosen from among all the fields in the village under wheat, both pure and mixed, and within a selected field, a plot of 1/20th of an acre (66′ × 33′) was located at random.

He stated that the entire field work was carried out by the revenue staff in the various districts under the administrative control of the Board of Revenue, United Provinces, with the full co-operation of the Director of Agriculture and his staff The organization for the work during the 1944–45 season was as follows:—

I *At Provincial Headquarters* —

(i) The Assistant Director of Land Records (in-charge of Statistics); and

(ii) The Statistician, Department of Agriculture, United Provinces.

II. *At District Headquarters* —

(i) The Officer-in-charge, Land Records, in each district; or, if for any reason, it was not possible to allot the work to him, another suitable Junior Civilian or Deputy Collector, as Officer-in-charge of the crop-cutting experiments on wheat;

(ii) A Senior Supervisor Qanungo.

III. *In Tahsils.*—

One or two Junior Supervisor Qanungos in accordance with the local requirements.

He then referred to the practical difficulties encountered in a few villages in the course of the field work. Although the cultivators all over the province generally co-operated with the revenue staff during the conduct of the experiments, it was noticed that a few of them had a lurking suspicion that their produce would be purchased by Government. In consequence, these cultivators were at first seriously opposed to allowing their fields to be experimented on and it was only after the object of the survey was courteously explained to them that their suspicions were allayed In a few other cases, on account of the prevailing high price of wheat, the cultivators were inclined to harvest their crops even when green and unripe for fear of theft of the produce and were with great difficulty persuaded to wait till the scheduled dates of harvesting of their fields fixed by the Junior Supervisor Qanungos. In a very few cases, the cultivators actually harvested the fields even earlier than the fixed dates for harvesting. In some stray cases, the dates of harvesting fixed by the Junior Supervisor Qanungos had to be altered as the crop in those areas had ripened earlier than expected on account of the blowing of dry westerly winds In such cases, the harvesting had to be done earlier than the dates fixed for the purpose and sometimes simultaneously with the selection of fields. In a few cases, when the village selected was unusually big and all the three fields were mature for experiments on the same day some difficulty was experienced in harvesting all the three fields in one day. In a few other cases, the three fields in a village did not ripen on the same day and the Junior Supervisor Qanungo concerned had to repeat his visits to such villages Although a Junior Supervisor Qanungo is in charge of part of a tahsil, called his Circle, he was required to conduct experiments in all the villages within his tahsil. He experienced considerable difficulty when working in villages falling outside his circle as he did not get full co-operation from the *patwaris* and other revenue staff of the areas outside his jurisdiction in the conduct of his work. These practical difficulties had been largely overcome in the crop-estimating survey on wheat during the 1945–46 *Rabi* season. The plot size had been reduced from 1/20th of an acre to 1/92·4 of an acre, the shape of the plot being an equilateral triangle of side 33 feet With the help of specially constructed triangular chains, it was now relatively easy to mark out this plot in the field Instead of employing one Junior Supervisor Qanungo in each tahsil, all the Supervisor Qanungos throughout the province had been trained up in the technique of carrying out the experiments and those Supervisor Qanungos in whose circles the selected villages fell were required to conduct the experiments in the villages within their circles.

Mr Kishen then briefly discussed the results of analysis of the data for the two surveys. It was found that for the 1943–44 survey, the sampling error expressed as percentage of the district mean yield in 26 out of the 45 districts was less than 10 per cent. Generally, in the district where the number of villages was about 40, the sampling error was about 6 per cent. In only three districts was the sampling error as high as 25 per cent. The sampling error of the provincial estimate of the mean yield was only 1·5 per cent. It was also found that the official forecast of wheat over-estimated the wheat out-turn by about 15 per cent. during the year 1943–44 and by about 10 per cent. during the year 1944–45 This over-estimation reflected on the accuracy of the existing official method of crop-forecasting. He then said that an idea regarding the number of experiments required to be conducted in each district and the province for obtaining estimates of the district mean yields with a given precision could be had from the following statement showing the number of villages required for the different percentages of standard errors:—

No of fields per village	No. of villages required for the different percentages of standard errors				
	2 p c	4 p c	5 p c	7 p c	10 p c
	981	245	157	80	39
	540	135	86	44	22
	452	113	72	37	18

A glance at the above table would show that in order to estimate the average yield of a district with 5 per cent standard error, 86 villages per district with 3 fields per village would be required to be selected On an average, that would mean a selection of about 22 villages in each tahsil of the province. That number was, however, too large for one Supervisor Qanungo to manage during the period of harvesting Even for a lower precision of 7 per cent , 44 villages per district or 11 villages per tahsil would be required, which was also rather large for one Qanungo. Experience had shown that with the staff of one Junior Supervisor Qanungo in a tahsil, six villages per tahsil or 25 villages per district could be conveniently managed. With that arrangement, it would be possible to estimate the average yield of each district with a standard error between 9 and 10 per cent. However, an error of 9 to 10 per cent. was too large to be useful to the administration. The only practical solution was the employment of all the Supervisor Qanungo in all the circles of the province and the distribution of the villages selected in each tahsil among all the Circle Qanungos in the tahsil, each Qanungos being required to carry out experiments in such of the villages as fall in his circle. The field work during the 1945–46 *Rabi* season had been organized on these lines and it was hoped that as a result of that step, it would be possible to estimate the district mean yields with increased precision, Mr. Kishen then referred to the unsatisfactory character of the statistics of out-turn for oilseed crops, such as linseed and mustard in the United Provinces. These crops were generally sown mixed with other crops and the estimates of their out-turn obtained by the existing official procedure were unreliable and largely conjectural. Confining attention to the linseed and rapeseed crops, for the sake of illustration, he remarked that there were as many as 18 crop mixtures, *e.g*, wheat-rapeseed, barley-rapeseed, gram-rapeseed, wheat-linseed, barley-linseed, gram-linseed, etc., which contained linseed or rapeseed as one of the constituent crops. The proportions of constituent crops in these mixtures were largely dependent on the whim of the cultivator who was mostly guided in the matter by purely economic considerations. Thus the proportions of the constituent crops varied widely from tract to tract in a given year and also from year to year for a given tract. A discussion was held in the province to effect improvement in the estimates of out-turn of oilseed crops sown mixed, and it was thought necessary to add as many as 36 columns (two for each of the 18 mixtures above) in the *Rabi* crop statement prepared by the *patwari* Furthermore, on account of the wide variation in the proportion of constituent crops in a mixture, it was also necessary to take into account these proportions for the purpose of conducting crop-cutting experiments and determining average yields per acre for linseed or rapeseed in each of the 18 mixtures for varying proportions of linseed or rapeseed. It was thus clear that some aspects of the problem of effecting improvement in the statistics of crop production in the United Provinces presented great difficulties and could not be overcome without the expenditure of a heavy amount of money, time and energy. However, it was fortunate that the problem of mixed crops was not so complicated in the case of important food crops.

Mr. Kishen concluded by saying that in the United Provinces, crop-cutting experiments on wheat and paddy on a province-wide scale had become more or less a permanent annual feature. In connection with the crop-estimating survey on wheat during the 1945–46 *rabi* season, it was the intention to train all the Circle Qanungos, about 700 in number, throughout the province in the technique of carrying out the experiments. With the help of that trained agency, it would be feasible to extend crop-cutting experiments to other important crops, *viz*, juar, bajra, maize, barley, gram, arhar, cotton and sugarcane in the immediate future. It was only by that means that the much needed improvement in the existing seriously defective statistics of crop production in the province could be effected.

Mr. G. R. Ayachit said that the official procedure for determining the normal yield provided for the conduct of crop-cutting experiments on average fields. In actual practice, however, these experiments were rarely carried out and where they were carried out the method was known to be defective as the selection of the fields was based on the personal notion of average. The correct procedure was to conduct these experiments in the fields selected on the principle of random sampling method This was recognised as far back as 1919. The Board of Agriculture recommended that crop-cutting experiments should be conducted on the principle of random sampling method Attempts were also made by Sir John Hubback in Bihar (1923-25) and later by Sir C D Deshmukh in Central Provinces (1928-30) to introduce the principle of random sampling method, for carrying out crop-cutting experiments. But these attempts did not leave a lasting impression on the methods followed by the provincial governments for conducting their crop-cutting experiments. The question naturally arose " Why were the Provinces carrying out the experiments by the old method when the random sampling method was the correct procedure ? " The plausible reason for this situation seemed to be that these earlier schemes had been formulated without full appreciation of the practical difficulties involved in the introduction of random sampling method for conducting crop-cutting experiments It was thought that these experiments required large additional staff and additional expenditure. To add to these there was also the unwillingness on the part of the provincial governments in introducing any thing that was different from the traditional departmental routine. These were the considerations kept in view when the Imperial Council of Agricultural Research formulated schemes of crop-cutting experiments on an all-India basis. It was obvious that if the random sampling method were to replace the existing procedure then only the minimum essential changes should be made in the current procedure so that experiments could be carried out by the existing departmental staff in the course of their normal duties, without heavy additional expenditure. Accordingly, those aspects of the scheme which did not vitiate the random character of the sampling method were retained in the new technique, *e g*, the size of the plot. It was considered that there was no particular advantage in changing the size of the plot to which officers and cultivators were accustomed under the old method. There was in fact a definite psychological advantage in not changing it. The results of the Moradabad district described by Dr. Sukhatme showed that their decisions to adopt the large plot size was a sound and a safe one as in all probability in earlier attempts the yield was over-estimated.

The first experiments by the random sampling method based on large size plots were conducted on wheat in the United Provinces and in the Punjab during the year 1943-44 The experiments were carried out by the staff of

Provincial Departments of Revenue in the United Provinces and Agriculture in the Punjab The entire field staff was trained by the I C.A.R. Statisticians. The field staff were required to send the returns to the centre as soon as the prescribed work was over. The returns were scrutinised as they were received and the data subsequently analysed. In view of the encouraging results of these surveys, the work was extended to paddy crop. Three pilot schemes were carried out in kharif season of the year 1944 in Raipur district in Central Provinces, in Tanjore district in Madras and in Kolaba district in Bombay. In the year 1944-45, the experiments on wheat were extended to C.P , Sind and N W.F P. in addition to U.P. and Punjab and experiments on paddy were extended to the whole of rice-growing belt of India excepting Bengal. The successful organization of these surveys involving the training of a large number of field staff of the provincial departments and covering a geographical area of India's size within a brief period of two years was a definite advance in the application of statistical science and was brought about by the efforts of the Imperial Council of Agricultural Research.

During the first year (1943-44), the total number of experiments conducted on wheat in Punjab and United Provinces were 2164 and 3444 and the mean yields were estimated with the sampling errors of only 1 5 and 1 4 per cent. respectively. The sampling error of the provincial estimates of mean yields in surveys conducted during 1944-45 also varied between one to three per cent It was interesting to compare the sampling estimates with the official ones. The first wheat survey in U P. showed that the official figure was an over-estimation to the tune of about 15 per cent. and these surveys in the Punjab showed that the official estimate was slightly an under-estimate by about 10 per cent The official estimate for N W F P. was also an under-estimate. In C P and Sind, however, the two estimates agreed within the margin of sampling errors. It was in the district estimates of yield that the real weakness of official figures lay. Thus in C P. although for the province as a whole the sample and the official estimates agreed within the limits of sampling error, the official figures in the individual districts were in considerable errors. In most of the districts the official estimate was higher than the sampling estimate and in six districts, the differences were significant Out of these six districts, four districts were from paddy tract of Chhattisgarh division and the official estimates for these four districts were higher than the corresponding sampling estimate by a margin going from 44 to 88 per cent. Equally according to sampling estimates there was a very large variation in the average yield from district to district, the range variation going from 2 19 maunds to 7 93 maunds per acre. The official figures, on the other hand, were relatively closely grouped around the provincial average 5·03, their range variation being 3·77 to 6·72 which was only about half the range of variation for the sample estimates This narrow range of variation in the official estimate of yield per acre was a direct consequence of the narrow range of variation of the district normal yield figures since the official yield was the product of the normal yield and the condition factor. It was apparent that if the crop-cutting experiments were repeated over a number of years, the resulting normal yields would be considerably different from those used by the Provincial Governments for calculating the official estimates of the yield per acre.

He further said that apart from estimating the yield the surveys could be utilised in obtaining useful ancillary information regarding other cultivation practices. The surveys also brought the staff of the Department of Agriculture in contact with interior villages which the staff had never visited in the course of their normal duties.

Sardar Labh Singh referred to his connection with the traditional method of crop-cutting experiments in the Punjab for over 20 years In this province an average field in an average village was selected for the experiment. This selection was definitely dependent upon the personal factor. But apart from this personal factor, there were other reasons for inaccuracies in the agricultural statistics As the origin of the collection of statistics relating to yields of crops was in connection with the commercial or administrative point of view, persons who had to collect yield data were inclined to be on the lower side to be sure that the land owners were not overtaxed. This was the reason why the official figures of cotton (normal yields) were much lower. The cultivators also, being afraid of increase in the land revenue, were ready to do whatever they could to lower the per acre value of the crop. In case of crops other than cotton, where the selection and harvesting can be done on the same day, there is a possibility of getting accurate results but in case of cotton where the harvesting is to be done in five to seven instalments and the crop had to remain for a period of two to three months on the field after the commencement of harvesting, the farmer through fear of increased assessment would in most cases try to interfere. He would try to pick some bolls, and stop irrigation and thus would deliberately try to lower the yield. Thus in spite of all the efforts to improve per acre value of yield there would be considerable danger of interference by the farmer and there would be a great tendency on his part to lower the yield. The land revenue policy was thus responsible for the inaccuracies in the agricultural statistics to a very considerable extent.

Mr. G. C. Shaligram said that apart from giving reliable estimates of actual yield, random sample surveys provided the best means of obtaining yield forecasts with a considerable degree of accuracy. These forecasts were most important from the point of view of commerce and industry. A careful eye-estimation of the crop in the sample plots, quantitative observations on components of yield such as number of plants per unit area and number of bolls per plant or other plant characters related to yield, amount of rainfall and other information could be utilized to make a reliable forecast of yield. Regression relationships of these quantities with actual yield obtained from the three years' surveys carried out on cotton in Central Provinces and Berar since the year 1942–43, were being studied with the object of obtaining suitable prediction formulæ

A considerable amount of ancillary information of both scientific and practical value could also be had from the sampling survey. This included various aspects of cultivation practices, spread of improved varieties and factors governing crop yield such as depth or nature of soil. This type of information was being collected in the surveys on cotton in Central Provinces and Berar. For example, the spread of improved cotton varieties was measured in the provincial survey in 1944–45 It was found that most of the cotton area in Berar was under the improved variety Jarilla while Central Provinces had only 7·4 per cent of the total area under this variety. It was also noted that the yields per acre of Jarilla in Berar was slightly higher than in Central Provinces and the difference was of the same order as the yield of all the varieties in the two tracts.

Mr. Pandit said that as one who was required to consult agricultural statistics frequently in the course of his work in the Planning and Development Department, he welcomed the attempts made by Drs. Sukhatme and Panse for improving the quality of yield statistics He said that it was essential that area figures should be known accurately for all crops and for all territorial units, because they were the basic figures upon which rested all other calculations of output of yield. For this reason alone, he said, he did not favour the use of the random sampling method. He watched with interest the use of this method for estimating acreage in Bihar and Bengal, but the results of the survey in Bihar showed that the margin of errror of the acreage estimates was too large for administrative decisions. He, therefore, strongly advocated that in the permanently-settled parts of the country and in the Indian States, *patwari* agency on the lines existing in the temporarily-settled parts should be immediately set up. It was a happy sign, he said, that in two of the three permanently-settled provinces they had appointed suitable land records organization for the enumeration of acreage.

He said that his remarks should not be taken to imply that all was well with area statistics in the temporarily-settled areas. Although, in his opinion, in the *patwari* agency an excellent and most suitable organisation existed for collecting acreage statistics, it was necessary to ensure that adequate and active supervision was exercised over their work to see that this agency worked satisfactorily in day-to-day practice.

Mr. V. B Sahasrabudhe said that it had been observed that the official estimates of yield per acre were generally higher than the actual yield obtained, when the season was unfavourable and *vice versa*. This resulted in narrowing down the range of yields in the individual seasons. This fact could be illustrated by comparing the following figures for Akola district for the three seasons 1942–43 to 1944–45 in which crop-cutting experiments were conducted on the cotton crop by the random sampling method.

Yield of Kapas in lbs per acre

	1942–43	1943–44	1944–45
Crop-cutting experiments	136	283	196
Official estimate ..	225	253	210

The results may be taken to represent three types of season, poor, good and medium. It would be seen that the value of the official estimate ranged from 210 to 253 lbs. while those from crop-cutting experiments ranged from 136 to 283 lbs.

The crop-cutting experiments conducted by the random sampling method provided reliable statistics for yield estimates and should, therefore, be conducted for a series of years to fix the standard or the normal yield for various crops. The standard or the normal yield was supposed to be the average of 5 to 10 seasons and should, therefore, be revised from time to time. This did not seem to have been done for the standard yield for cotton for Akola district, as the present standard of 320 lbs. of kapas was being used for the past several years. It would be interesting to note that this figure was very much higher than the average yield obtained by the crop-cutting experiments in the three seasons mentioned above. Even the average yield obtained from the crop-cutting experiments conducted by the provincial agricultural and land records departments which were published in the season and crop reports were below the present standard for Akola district.

Dewan Bahadur K. R. Ramanathan who took the chair from 3-45 P.M. to 6 P.M., wound up the proceedings. He asked for figures for the cost of surveys on wheat and cotton conducted by the Imperial Council of Agricultural Research and the Indian Central Cotton Committee and those incurred by Prof. Mahalanobis in his survey in Bengal, then made a brief comparison of the two and expressed his satisfaction at the low cost and efficiency of the Imperial Council of Agricultural Research method. He said that as a meteorologist his experience was that the yield per acre varied considerably from plot to plot owing to the large differences in the weather conditions and said that random sampling was the only objective method for arriving at an unbiased estimate of the average yield. He expressed the hope that these surveys would be taken up as an annual departmental routine on a permanent basis by the Provincial Governments in years to come.

MORPHOLOGICAL AND CYTOLOGICAL STUDIES IN SCROPHULARIACEÆ

V. *Striga euphrasioides* Benth.

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I. Introduction

The genus *Striga* includes parasitic species which by forming haustorial connections with roots of the host plants cause extensive ravages upon crop plants. The development of embryo in this genus has not been sufficiently investigated, an old account only remaining about *Striga lutea* (Mitchell, 1915). Cytological work has however been made in this genus recently by Kumar and Abraham (1941) where they have given an account of the chromosome numbers in this genus and traced the development of the anther wall. The present study is a continuation of a series of papers from this laboratory on Scrophularineæ (Srinivasan, V. K., 1940; Raghavan and Srinivasan, V. K, 1940, 1941 *a* and 1941 *b*). A review of cyto-morphological work in this family has been given in the first paper in this series. The present communication deals mainly with the development of endosperm in *Striga* *euphrasioides* Benth. and some details of megasporogenesis and embryo development.

II. MATERIALS AND METHODS

Observations were mostly made from slides prepared in this laboratory by Mr. V. K. Srinivasan, M Sc, which were kindly given to me by Dr. T. S. Raghavan. Some fresh slides also were prepared from materials collected locally. The ovaries were fixed in formalin-acetic-alcohol and sections were taken by the paraffin method and stained in Haidenhain's Hæmatoxylin

Striga euphrasioides Benth. is one of the common weeds of South India. Though reported and described as a parasite, it was not possible to trace the parasitic relationship of this plant with any of the grasses growing nearby in spite of careful efforts Gamble (1924) makes a similar remark also in that "it is parasitic and destructive on crops of Sugarcane and Sorghum, but this is not recorded from Madras".[1]

The plant is a scabrid herb covered with stiff short hairs with dark green or greyish stems The plant is crustaceous and rough to feel due to its scabrid nature. The leaves are opposite below and alternate above, linear, up to two inches long and with 1 to 2 teeth on their margins. Flowers are solitary in the axils of the leaves. Calyx 15-ribbed, all ribs being continued to the tips of the lobes. Corolla tube slender, abruptly incurved about the middle. Upper lip two-lobed and the lower three-lobed. Stamens four, didynamous. Ovary bicarpellary, bilocular with a fleshy axile placenta with numerous ovules. The fruit is an obovoid capsule.

III THE OVULE

The ovule first arises as a pappillate protuberance from the placenta. After the differentiation of the single hypodermal archesporium the ovule becomes bent towards one side due to unilateral growth. There is a single massive integument, the primordium of which is differentiated just at the time when the ovule becomes bent (Fig. 1). By the time the archesporium gets elongated to form the megaspore mother cell, the integument grows half way up the tip of the ovule (Fig. 2) It reaches the level of the nucellus during the early megasporogenesis stages (Fig. 3). From now onwards its growth is more rapid and it grows past the nucellus partly crushing it and forms the micropylar canal even before the functioning megaspore is organised into the uninucleate embryo-sac (Fig 4)

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[1] It is interesting to note in this connection, that *Striga euphrasioides* germinates to a fairly high extent (44%) even without host stimulus under certain conditions (Kumar and Solomon, 1940)

The nucellus is also of the reduced 'tenuinucellate' type (Schnarf, 1929) which is common in Sympetaleæ, though exceptional cases in Polypetaleæ show such a type, *e.g.*, *Vahlia* (Raghavan and Srinivasan, V. K., 1942). There is a single layer of nucellus covering the archesporium on all sides except the chalazal one (Figs. 2 and 3). This nucellus, as is always the case with 'tenuinucellus', is short-lived. It is crushed between the developing massive integument on the outer side and the growing functioning megaspore inside and finally disintegrates (Figs. 3 and 4)

The ovule becomes completely anatropous during the late embryo-sac stages.

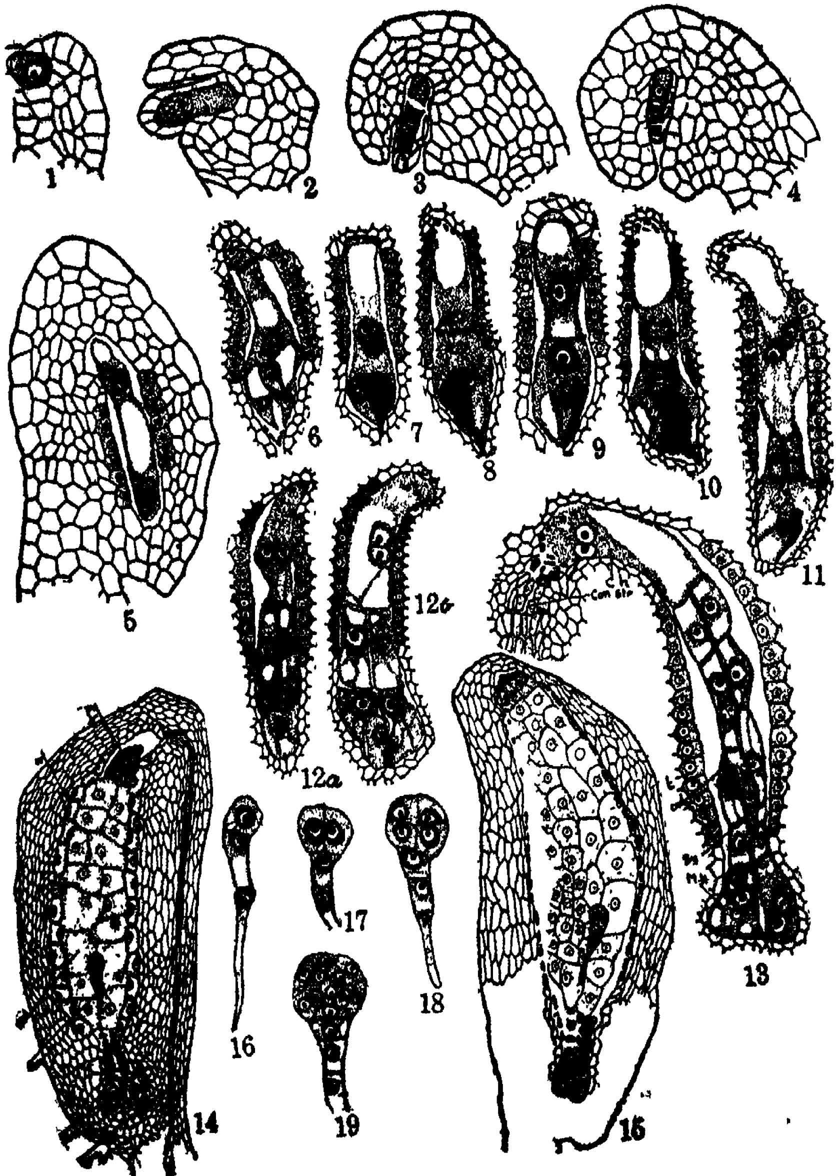
IV. MEGASPOROGENESIS AND EMBRYO-SAC

The archesporium of the megaspore is made up of a single hypodermal cell at the tip of the ovule which becomes distinguished from the rest of the ovular tissue by its larger size, prominent nucleus and dense cytoplasmic contents (Fig. 1). As in all sympetalous families, this does not cut off any parietal cell, but functions directly as the megaspore mother cell after elongating longitudinally The nucleus of the megaspore mother cell is situated at its micropylar end (Fig. 2).

As a result of the meiotic divisions of the megaspore mother cell, a linear tetrad of megaspores is formed of which the chalazal one functions. The functioning megaspore gives rise to the eight-nucleate embryo-sac through three divisions, the first two divisions resulting in the two-nucleate and the four-nucleate embryo-sacs respectively (Figs. 4-6) Thus the development of the embryo-sac conforms to the monosporic normal type (Maheshwari, 1937).

The polar nuclei fuse early in the ontogeny of the embryo-sac; the mature embryo-sac is seven-celled. The antipodal cells also are ephemeral and undergo degeneration at this stage (Fig. 6). The synergids are large cells with basal vacuoles; the egg cell lies between the synergids. The egg cell is not longer than the synergids and so does not protrude beyond the vacuolar region of the synergids (Fig. 6). The synergids degenerate after fertilisation, as is commonly the case. It is however to be noted that the synergids are reported to be persistent in another genus of this family, *Angelonia* (Srinivasan, V. K., 1940).

The pollen tube enters through the micropyle and effects fertilisation. The synergids are destroyed during this process. The remains of the pollen tubes are seen upto later stages in the endosperm development as darkly staining patches near the zygote (Figs. 7-11)



TEXT-FIGS. 1-19

FIG. 1. Archesporium of the megaspore Primordium of the integument is just differentiated.
FIG. 2. Megaspore mother cell
FIG 3. Linear tetrad stage showing the nucellus just beginning to degenerate.
FIG 4. The same stage with the micropylar megaspores degenerating The nucellus has completely degenerated.
FIG. 5. Four-nucleate embryo-sac Integumentary tapetum formed
FIG 6 Mature embryo-sac. Antipodals degenerated and polar nuclei fused
FIG 7. Zygote and primary endosperm nucleus
FIG 8 First division (Transverse) of the endosperm nucleus
FIG 9 Two-celled endosperm
FIG 10 Division in both the endosperm cells
FIG 11 Three-celled endosperm Two micropylar cells and a binucleate chalazal chamber formed. Division (transverse) in the micropylar cells
FIG 12*a* Five-celled endosperm The two cells just surrounding the embryo form the micropylar haustorium, the lowermost binucleate cell forms the chalazal haustorium and the two cells in the middle divide and produce the endosperm tissue
FIG 12*b* Transverse division in the central endosperm cell which gives rise to the endosperm
FIG 13 Chalazal haustorium invades and curves back into the integumental tissue, *M.H*—Micropylar haustorium (binucleate) *Zy*—Zygote *End*—Endosperm *T*—Tapetum. *C H.*—Chalazal haustorium *Con str*—Conducting strand
FIG 14 Condition of ovule and tapetum during the two-celled embryo stage Signs of degeneration in the haustoria are seen
FIG 15 Ovule in the quadrant stage of the embryo Tapetum and haustoria completely degenerated
FIGS 16–19 Embryo stages Explanation in the text

All figures except 14 and 15 are of magnification × 450 Figs. 14 and 15 magnification × 200.

V THE TAPETUM

During the mature condition of the embryo-sac and its later stages, it is seen to be surrounded on the sides by the integumentary tapetum (Figs. 6–13). Mitchell (1915) has said that no integumentary tapetum was observed in *Striga lutea*. In this species, however, the tapetum is present right from the four-nucleate embryo-sac stage (Fig 5), but it is more clearly defined from the mature embryo-sac stage onwards Mitchell's observation of the non-occurrence of tapetum in a closely related species is interesting. Whether a fairly important character such as this is likely to differ even within a genus, can be determined only by investigating the other species of *Striga* That it is not however universal in this family, is indicated by its reported absence in *Angelonia* (Srinivasan, V. K, 1940) In this species however there can be no doubt as to the formation of the tapetum which becomes more well defined in the early post-fertilisation stages (Figs. 7–13). The tapetum at all stages of development covers only the sides of the embryo-sac leaving ordinary cells at the micropylar and the chalazal ends. In longitudinal sections of the ovule, it is seen to be six to seven-celled in the four-nucleate embryo-sac stage when only it is distinguished (Fig 5), and ten to twelve-celled in the mature embryo-sac and the post-fertilisation stages (Figs. 6–10). As the embryo-sac elongates after the division of the endosperm nucleus, the tapetum also correspondingly increased in length reaching a maximum of 15 to 18 cells from the three-celled endosperm stage onwards (Figs. 11–13) After this, the tapetal cells which were more or less square in shape and densely cytoplasmic, become tangentially elongated and vacuolate (Fig. 14). They are uninucleate throughout and degenerate shortly after the quadrant stage of the embryo (Fig 15).

VI. THE ENDOSPERM

To start with the primary endosperm nucleus is located in the central portion of the embryo-sac (Fig. 7) A large vacuole is formed towards the chalazal end of the embryo-sac The first division of the endosperm nucleus takes place transversely resulting in two daughter cells one superposed on the other (Figs. 8 and 9) Thus the endosperm development is cellular which is a common feature in Sympetaleæ This is however by no means the rule For example in Rubiaceæ (Raghavan and Rangaswamy, 1941; Raghavan and Srinivasan, A. R, 1941), Asclepiadaceæ, Apocyanaceæ, Convolvulaceæ, Loganiaceæ, etc (Schnarf, 1929), the free-nuclear endosperm is the prevalent condition.

Of the two daughter cells of the primary endosperm cell, the micropylar cell divides longitudinally to form two cells In the chalazal cell, only the nucleus divides resulting in a binucleate chalazal chamber (Fig. 10) The division in these two cells may be simultaneous or one may precede the other, generally the micropylar cell dividing earlier Thus a three-celled endosperm is formed of which the lower does not divide any more. No wall formation ever appears to take place in this cell which directly functions as the chalazal haustorium This three-celled type of development has been recorded in *Striga lutea* (Mitchell, 1915). Krishna Iyengar (1939 *b*) has reported in *Stemodia* and *Limnophila* a uninucleate chalazal chamber instead of the binucleate one observed in *Striga* Srinivasan, V K (1940) has however reported the two-celled chalazal haustorium in the same species of *Stemodia*. In *Rehmannia angulata* (Krishna Iyengar, 1942) the formation of the haustorium from the chalazal chamber is reported. The number of nuclei vary from two to five but generally it is two and at times an incomplete longitudinal wall is formed in this chamber. So this two-nucleate unicellular chalazal haustorium is not uncommon in this family. Sometimes unicellular condition of the chalazal haustorium may be secondarily derived by the disintegration of the longitudinal septum as is described for *Vandellia* (Srinivasan, V. K, 1940) and *Bonnaya* (Krishna Iyengar, 1940). Unicellular chalazal haustorium has been observed in plants belonging to allied families. In *Pedalium* (Srinivasan, A R, 1942) it is unicellular and four-nucleate. In *Stachytarpheta* (Tatachar, 1940), it is two-nucleate as in the present case

While the chalazal chamber thus remains unchanged, transverse divisions take place in the two micropylar cells (Fig 11) Thus two tiers of two cells are formed (Figs. 12 *a* and *b*) Of these, the micropylar pair forms the haustorium at that end and the two central cells by further divisions give rise to more endosperm cells (Fig 12 *b*) Only transverse divisions take place at this stage thus forming only two rows of cells Later however longitudinal divisions follow which increase the size of the endosperm in bulk (Figs 13-15)

The micropylar haustorium is not very aggressive The cells become binucleate (Fig 13) and later by the fusion of these nuclei we get two uninucleate cells as seen in Fig. 14. Mitchell (1915) has observed this non-aggressive nature of the micropylar haustoria and says that "no definite haustorium is formed though the cells of the endosperm grow a short distance up the micropyle surrounding the suspensor and are probably to be considered as having a haustorial function" The endosperm cells around the suspensor and those formed at the base of the micropylar chamber have dense protoplasm and stain far more deeply than the surrounding cells of the endosperm

Both the chalazal and the micropylar haustoria begin to degenerate soon after the division of the zygote (Fig 14) Though the chalazal haustorium appears the endosperm cells near it becomes elongated longitudinally and stain deeply (Fig. 15) This densely cytoplasmic group of cells at the chalazal end probably take over the function of the chalazal haustorium during the later stages when the haustoria have ceased to exist This surmise is further supported by the fact that these cells persist until very late stages in the development of the embryo and retain their healthy and cytoplasmic nature.

VII. THE EMBRYO

The zygote divides rather late after about 12-15 endosperm cells are formed. Thus the embryo development is initiated only after a well-established nutritive tissue is organised around the oospore Two successive transverse divisions in the zygote result in the formation of a three-celled proembryo (Fig. 16) The lowermost suspensor cell becomes very long pushing the proembryo nearly to the centre of the embryo-sac (Figs. 13 and 14). Of the three cells the terminal cell undergoes two longitudinal divisions in planes at right angles to one another resulting in the organisation of the quadrant stage (Fig. 17). The quadrant cells undergo a periclinal division to result in the octant (Fig 18) By this time another periclinal division takes place in the uppermost suspensor cell making the suspensor three-celled.

Oblique walls are laid down in the octant cells differentiating the dermatogen from the central core (Fig. 19) The cell of the suspensor in contact with the proembryo undergoes another periclinal division. The upper daughter cell forms the hypophysis and takes part in the formation of the dermatogen of the root, while the lower forms part of the suspensor. Further divisions in the cells of the embryo lead to the lobing of the cotyledons.

VIII. DISCUSSION

(*a*) *The integumentary tapetum*—In a previous paper, Raghavan and Srinivasan, V. K. (1942) discussed at some length the role of the integumentary tapetum in the light of its correlation to the nucellus and the endosperm. Nuclear type of endosperm such as is found in the Polypetaleæ is associated with a massive nucellus and two thin integuments. In them, tapetum is conspicuous by its absence. There are however exceptions to which reference has been made by the said authors. In the Sympetaleæ the reduced type of nucellus or the "tenuinucleate" condition is the general rule A correlation seems to exist between these observed facts Where there is massive parietal tissue—"the krassinucellus"—the nutrition of the embryo-sac is presumably defective To make up for this defective nutritive mechanism the tapetal layer has come in Special chalazal integumentary tissues enclosed by the tapetum occur in some cases to aid the tapetum in its nutritive role, *e g*, *Limnanthemum* (Srinivasan, A. R., 1941) and *Lobelia trigona* (Kausik, 1935). The tapetum is associated with cellular endosperm any of which show one type of haustoria or another The implication is that the nutritive mechanism not being perfect, recourse has been taken to these supplementary devices to make up for the deficiency The question whether the integumentary tapetum functions much in the same way as the microsporangial tapetum—*i e.*, by contributing directly nutritive materials—or, acts merely as a liaison tissue, has also been discussed in the previous paper under reference (Raghavan and Srinivasan, V. K., 1942). The tentative conclusion then reached that it acts more as a liaison tissue than anything else, seems to be confirmed by observations made in this paper.

The predominantly nutritive function of the tapetum should not blind us to its mechanical function of protection which is no less important. This is often overlooked except in some special cases where the tapetum is persistent. As the functioning megaspore enlarges considerably during its development, it makes room for itself by crushing the surrounding nucellar cells. In the case of three polypetalous families, there is a massive nucellar tissue which becomes thinned down as the embryo grows digesting the substance of the crushed cells immediately surrounding it. It is quite common that in all these cases the degenerated nucellar cells are found surrounding the embryo-sac.

In all such ovules there are two integuments which are mainly protective in function and seem to play very little part in the nutrition of the embryo-sac. As there is a massive nucellus which is in contact with the funicle, the embryo-sac is feeding itself upon this nucellus and both the integuments are left completely intact upto the seed stage when they form seed-coats.

In the Sympetaleæ however, the role of the integument changes. The thin and the fragile nucellus does not persist beyond megasporogenesis stages It degenerates leaving the massive single integument to come in contact with the embryo-sac. The single integument has to serve a dual function here, *i.e.*, of nutrition and protection of the embryo-sac. Hence the tapetum is formed. If we examine the nature of tapetal tissue and its behaviour during the development of the embryo-sac, we will find that it plays the protective role to a greater extent than is ordinarily ascribed to it.

Firstly it is a layer of compactly arranged cells covering the embryo-sac at least on the sides The cells appear healthy and firm capable of withstanding pressure exerted by the developing embryo-sac. Moreover, these cells are not affected by the developing embryo-sac, but retain their original size and shape until late in the post-fertilisation stages, when they degenerate. The degeneration of the tapetal layer takes place only after the formation of endosperm which takes over the nutritive role and partly the protective role also. For, in many of the 'tenuinucellate' ovules the outer endosperm layers become cutinised serving as a protection to the underlying tissues after the degeneration of the tapetum. The integument in all these cases forms a flimsy covering of one or two layers of cells over the hard endosperm and thus is of no protective value.

(*b*) *Endosperm and nutritive devices* —The preliminary role of endosperm is to nourish the developing embryo. It is the tissue from which the embryo absorbs its food directly. Thus it plays a direct role in the nutrition of the embryo. In the case of the nuclear endosperm it is able to perform this function without taking recourse to any special devices, for, the endosperm itself lies embedded within the massive nucellus from which it directly takes the food requirements of the embryo In the case of the cellular endosperm on the other hand, many devices are adopted to perform this function of absorbing food from the massive integument and pass it on to the endosperm. Some of the main types of these devices and the way in which they help the endosperm are briefly indicated.

First of all the suspensor haustoria may be considered, for they arise directly from the cells of the embryo and consequently play a direct role in the nutrition of the embryo. These are formed from the cells of the suspensor as large outgrowths which branch profusely and ramify the integumentary tissue. There seems to be no correlation between the occurrence of these and the type of endosperm. It occurs associated with nuclear endosperm (Lloyd, 1902) or with cellular endosperm (Rangaswamy, 1941)

The parts of the embryo-sac which remain persistent often play a haustorial role. These serve as absorbing organs which pass on the nutritive materials absorbed by them to the endosperm, where they get stored up Persistent synergids have been reported to perform haustorial functions in *Angelonia* (Srinivasan, V. K , 1940) Antipodals which are normally ephemeral, divide and multiply to form a special haustorial tissue connecting the endosperm and the integumentary tissues These occur generally in some genera of Rubiaceæ and Compositeæ (Schnarf, 1929, p 355) In *Rudbeckia bicolor* (Maheshwari and Srinivasan, 1944) the antipodals are far larger than the cells of the egg apparatus and one of them persists even upto the time of differentiation of the cotyledons. This was said to be suggestive of an "antipodal oospore" by the authors. Presumably these serve some haustorial function also.

The nutritive significance of the tapetum has been discussed in the first half of this discussion The other main device is the formation of endosperm haustoria These are exclusively formed by the cellular endosperm. The division of the primary endosperm nucleus results in three tiers of cells of which the cells at the micropylar and the chalazal ends are differentiated into the micropylar and the chalzal haustoria Both the haustoria always occur together though one of them may sometimes be less aggressive and consequently less prominent than the other, *e.g* , *Striga*.

The number of haustorial cells may vary from one to four. In the case of *Celsia* and *Isoplexis*, four-celled haustoria occur at both ends of the embryo-sac (Krishna Iyengar, 1939 *a*). It often happens that the cross-walls disintegrate in the four cells and result in a tetranucleate cell, *e g* , *Vandellia* (Srinivasan, V. K., 1940) Both haustoria are two-celled in *Hysanthes* and *Scoparia* (Raghavan and Srinivasan, V. K , 1941 *a* and *b*). Other conditions may occur in which the two haustoria differ in the number of cells composing them. For example we get in *Striga* two-celled micropylar haustorium and single-celled chalazal haustorium. In *Bonnaya* (Krishna Iyengar, 1940) the micropylar haustorium is four-celled while the chalazal is one-celled.

The endosperm haustoria have been classified into definite types according to their final configuration (Krishna Iyengar, 1940). The number of cells composing the haustoria are held to be the criterion to assess their primitive and advanced nature. Thus the type met with in *Celsia* with four-celled haustoria at both ends of the embryo-sac forms the most primitive and the type met with in *Striga* with two micropylar cells and one chalazal cell forms the most advanced.

IX SUMMARY

The embryo-sac development in *Striga euphrasioides* Benth. is of the monosporic type.

The integumentary tapetum is present and functions till late post-fertilisation stages.

The endosperm is cellular Micropylar and chalazal haustoria are formed of which the former is two-celled and less aggressive and the latter single-celled.

The correlation between 'tenuinucellus', integumentary tapetum and cellular endosperm is discussed in the light of the nutrition of the embryo-sac and embryo The protective role of the integumentary tapetum is emphasised.

The various devices for the nutrition of the embryo-sac are briefly indicated with special reference to the endosperm tissue.

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STUDIES IN GALERUCINAE

The Internal Anatomy of *Galerucella birmanica* (Jacoby), Coleoptera, Polyphaga, Phytophaga, Chrysomelidae, Galerucinae

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I. INTRODUCTION

In a previous paper (Khatib[14]) a detailed account of the External Morphology of *G. birmanica* was attempted. The Internal Anatomy as well of this important group of beetles is very poorly known and hence no apology is needed to undertake this study. During the course of this investigation it was found that this beetle presents certain interesting features in the arrangement and distribution of the Malpighian tubules and tracheæ.

II. TECHNIQUE

All dissections were made under normal saline or Ringer's solution with the help of a powerful dissecting microscope. Monla lamp was found to be most useful in giving a steady light when certain dissections had to be done under very high magnification. Much difficulty was experienced in tracing the course of the Malpighian tubules as long immersion of the fresh tissues even in normal salt solution was followed by their histolysis and subsequent disintegration. This was overcome by treating the material with Bouin's fluid for about five minutes after the animal was opened under normal saline and got rid of all superficial fat. It was further found advantageous to wash the freshly dissected tissues with tap water prior to treating it with Bouin. After this preliminary treatment with Bouin the material was transferred to 50 % alcohol and the entire dissection was carried out under the latter. This method has two advantages: 1. any disintegration of tissues is prevented and the tissues do not get hard enough to prevent handling; 2 the Malpighian tubules acquire a yellowish tinge which renders their tracing much easier.

For sectioning the freshly dissected parts were fixed in Carnoy's fixative or alcoholic Bouin and sectioned in the usual way. For sectioning the entire insect the usual double imbedding method was tried but the freshly emerged beetles could be sectioned even with the usual paraffin method. The fixatives most extensively used were Bouin's (alcoholic) and Carnoy's with Mercuric Chloride. Both these fixatives gave satisfactory results. The specimens after the usual process of dehydration were transferred to pure Benzene for an hour and then to a saturated solution of wax in Benzene at 25 degrees temperature Here the material was kept for about two hours and then brought to pure wax of 56–58 degrees melting point and allowed to remain there for about twenty-four hours with at least two changes so that all traces of Benzene were removed. Sections were cut 8–10 microns thick and arranged on slides thinly smeared with Mayer's albumen After removal of the wax they were given a dip in a thin solution of Colloidin in absolute alcohol and at once plunged in 70% alcohol for about five minutes in order to allow the Colloidin film to harden This treatment of the mounted sections with Colloidin does not allow them to fall off during the subsequent processes of staining and dehydration. Sections not covered with this thin film of Colloidin were invariably found to loose many a structure. Several stains were tried but Borax Carmine-Picro-Indigo-Carmine and Mallory's triple stain gave the best results.

III THE ALIMENTARY CANAL

The alimentary canal consists of a simple tube with few convolutions (Fig 1). Throughout its length it is surrounded by a thick layer of adipose tissue. The relative abundance or otherwise of this tissue varies with the time of the year and the amount of food. It was found that at the close of the active life of the beetle when it prepares for hibernation, the fat in the body increases considerably, so much so that on removing the tergites in a freshly killed specimen nothing but fat could be seen. In Fig. 1 the alimentary canal is seen *in situ* as it appears after clearing away the fat.

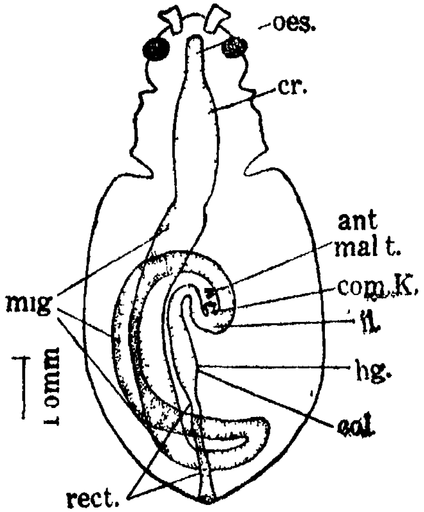


FIG. 1. Alimentary canal *in situ*

1 *The Fore-Gut*—This is a short tube consisting of the pharynx, œsophagus, crop and the œsophageal valve There is no gizzard (Fig 3)

(*a*) *The Pharynx*—From the dorsal side the pharynx (*Ph.*) cannot be properly seen as it bends downwards towards the mouth. The inner lining of the pharynx is provided with a number of chitinous bristles and passes forward into the extra-oral mouth cavity Its dorsal wall is supported by a pair of chitinous rods arising from the tormæ of the labrum

(*b*) *The Oesophagus*—The œsophagus (*oes*) is a very short and narrow tube connecting the crop (*cr*) with the pharynx and is not very clearly marked out from the latter. Posteriorly it is marked off from the crop by definite constriction. Its inner lining like that of the pharynx is provided with a number of bristles.

(*c*) *The Crop.*—The crop (*cr*) extends from the posterior region of the head to the anterior end on the prothorax. The œsophageal valve (*oes v.*) is well developed and marks the division between the fore- and the mid-gut internally. Externally the two divisions of the alimentary canal are marked out by very slight constriction.

2. *The Mid-Gut*—The mid-gut is the longest portion of the alimentary canal (Figs. 1–3) Anteriorly it is marked off from the fore-gut by a slight

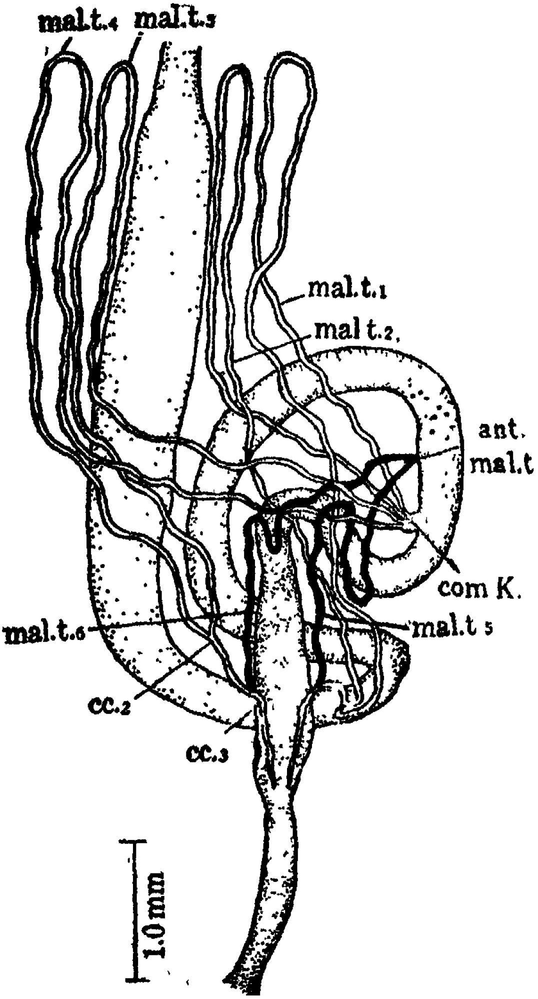


Fig. 2 Alimentary canal showing the course of Malpighian tubules.

constriction and posteriorly from the hind-gut by the insertion of the second group of Malpighian tubules (*com d.*). The first group of two Malpighian tubules (*ant. Malp. t.*) are associated with the mid-gut. According to Mansour[17, 18] the adult mid-gut development in Chrysomelidæ is of Ptinus

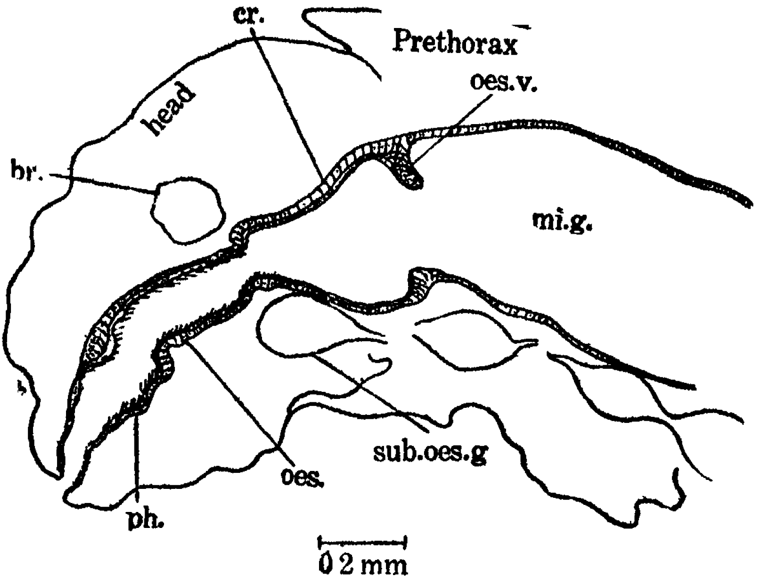


Fig 3 V L S Head and Thorax

type where it develops from the end of the stomodæum during metamorphosis

3 *The Hind-Gut*—The hind-gut can be divided into ileum (*il*), colon (*col.*), and rectum (*rect.*). The distinction between the first two divisions is not at all sharp but the rectum is marked out very clearly from the colon by its very thick muscular lining and by the abrupt ending of the Malpighian tubules at the posterior limit of the colon The rectum passes backwards to open on the ventral surface of the rudimentary 9th tergum. The innermost lining of the rectum is highly chitinized and thickened The epithelial cells have no cell boundaries and the nuclei are in the form of a syncitium. There are no rectal glands.

4. *The Malpighian Tubules*—The question of the ectodermal or the endodermal origin of the Malpighian tubules has been much discussed of late years. Though most of the workers have ascribed an ectodermal origin to them (Heymons and Luhmann, and others), there are some (Henson[9]) who regard them to be endodermal in origin. According to Mansour[17, 18] the mid-gut itself is ectodermal in origin in various insects he had studied. Recently Roonwal[28] in his excellent memoir on the embryology of *Locusta*

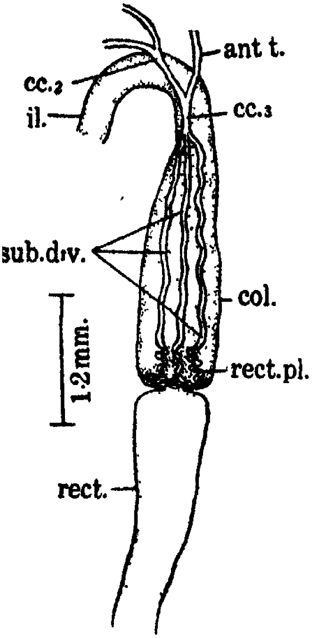


Fig 4 Colon and Rectum
(left side view)

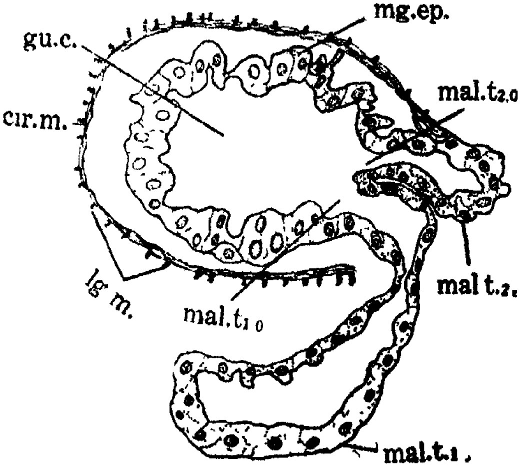


Fig 5 Transverse section of Alimentary canal passing through the region ant mal. t in Fig. 2
×300

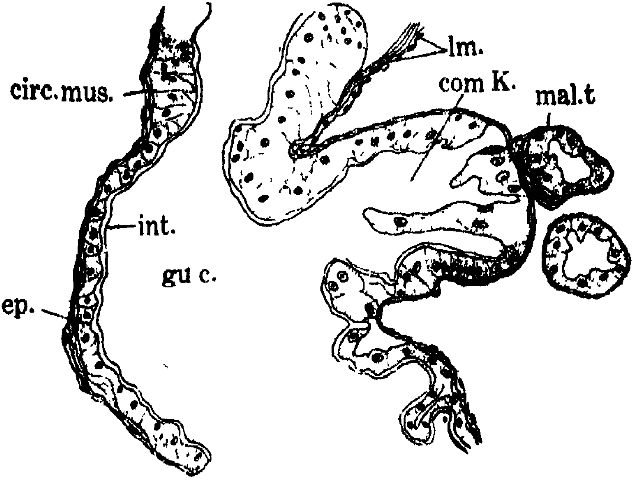


Fig. 6. Transverse section of Alimentary canal passing through the region of Com. K. in Fig. 2, ×300

Migratoria migratorioides has brought forward evidence to show that the definitive mid-gut epithelium in this insect is ectodermal in origin. Further he is of opinion that Henson's homology of the Stomodæal and Proctodæal invaginations of Pieres' embryo with the oral and anal remnants of the blastopore in Peripatus is not correct "The blastopore of Peripatus is formed simultaneously with the differentiation of the endo-mesoderm The stomodæal and proctodæal invaginations of Pieris, on the other hand, appear long after the differentiation of the endo-mesoderm (inner layer) Consequently the stomodæum, the proctodæum, and the Malpighian tubules be regarded as purely ectodermal." (Roonwal[28])

The Malpighian tubules in *G. birmanica* arise in two groups. A posterior group of four tubules arising from a common duct (*com d*), and an anterior group arising separately although very close to one another (Fig 6, malt 10, malt 20) Proximally these two tubules are enclosed in a common fascia which apparently gives an impression of their arising by a common duct, but a section of the alimentary canal in this region (Fig 6) clearly shows their separate openings in the gut cavity. Heymons and Luhmann[10] have shown that in *Galerucella viburni* the anterior pair arises from the mid-gut and the posterior pair by a common handle from the hind-gut The author is in complete agreement with their account so far as the origin of these tubules in two groups is concerned but there are certain fundamental differences between his observations in *G birmanica* and the arrangement described by Heymons and Luhmann in *G viburni* with regard to the attachment of tubules to colon and the union of the anterior pair of tubules with the posterior pair. This will be described in the account that follows

The course of the Malpighian tubules—The course of the Malpighian tubules is shown diagrammatically in Fig 2 and in general resembles that described by Davidson[8] in *Cirocercus asparagi* The common stem (*cc* 3) is shown much posteriorly in this diagrammatic sketch for the sake of clarity. The actual place of formation of this common stem and its ultimate fate is indicated in Fig 4. Out of the four tubules which arise from the common knob (*com k*) the two outer ones (*mal* t_1 and *mal.* t_4) run along the ventral side in close association with the ventral nerve cord and the two inner ones (*mal.* t_2 and *mal* t_3) run along the dorsal side of the alimentary canal. Both the pairs run cephalad as far as the crop, one pair to the right the other to the left, where they bend sharply backwards and following a sinuous course reach the anterior portion of the colon The two tubules of the left side meet together to form a common stem (*cc* 2) which becomes intimately attached to the left side of the colon. This common stem is joined by one of the tubules of the anterior group and the three together form the main stem (*cc* 3). Same is the fate of the tubules of the right side. Heymons and Luhmann do not see in *G. viburni* an opening of one of the tubules of the anterior pair into the common stem which is formed by the posterior pair. They say that it just rests upon this common stem and illustrate the same in their diagram. Further they have observed a chamber-like space in the wall of the colon in which this common stem opens No such chamber-like space is seen in *G. birmanica* and the anterior tubules actually communicate with the lumen of the common stem thus forming the main stem. The two tubules of the anterior group (*mal* t_5 and *mal* t_6) are much smaller in length than those of the posterior group and follow a more sinuous course in the body cavity closely associated with the ileum and colon. Each of these is finally united with one of the common stems described above. The main stem formed by the union of the three tubules on either side becomes applied to the colon and is enclosed in its peritoneal membrane. Soon, however, this stem splits into its component parts still retaining lateral position. In a series of transverse sections it is seen that as the posterior region of colon is reached these tubules spread more and more along its ventro-lateral areas Fig 7 shows the arrangement of tubules in the middle

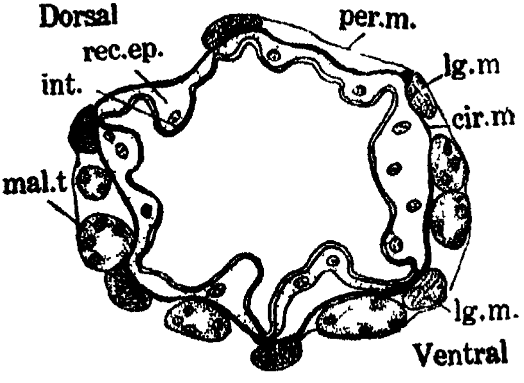


FIG 7 Transverse section through the middle of colon. × 253 3

of the colon. The dorsal side of the colon has no tubules. There are three bundles of longitudinal muscles lying on the ventral side of the colon. One of these is mid-ventral in position and lies between the two ventral tubules. Of the other two bundles of longitudinal muscles one is situated between the ventral and the two lateral tubules of the right side and the other is similarly situated on the left side. There are three more bundles of longitudinal muscles (*lg. m.*) in the wall of the colon, one dorsal and two dorso-lateral. Below the layer of the longitudinal muscles there is a thin layer of circular muscles (*cir. m.*) intervening between the Malpighian tubules and the hind-gut epithelium. As the posterior limit of the colon is reached, the tubules become more and more sinuous and in sections of its posterior-most region, these tubules form a sort of plexus and completely cover the colon (Figs 8 and 9). The circular layer of muscles fades away and the longitudinal bundles also split up and become insignificant in this region. The very poor development of the longitudinal layer of muscles in this region can be attributed to the more or less uniform covering of the Malpighian tubules. It is in the posterior region of the colon that a very close association is established between the epithelium of colon and that of the Malpighian tubules. The Malpighian tubules never open into the colon,

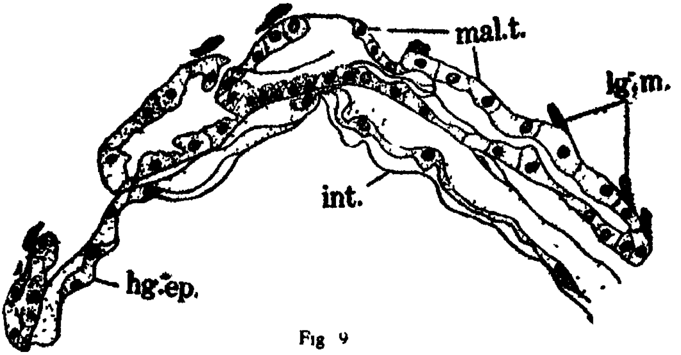


Fig 9

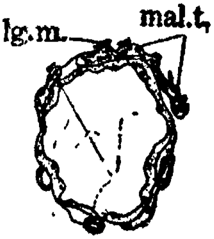


Fig 8

Fig. 8. Transverse section through the posterior region of colon × 80.
Fig 9 Upper half from Fig. 8 × 300

IV. THE DORSAL VESSEL

The heart (Figs. 10 and 11) is a tubular structure extending from the last abdominal segment to the posterior region of the mesothoracic segment.

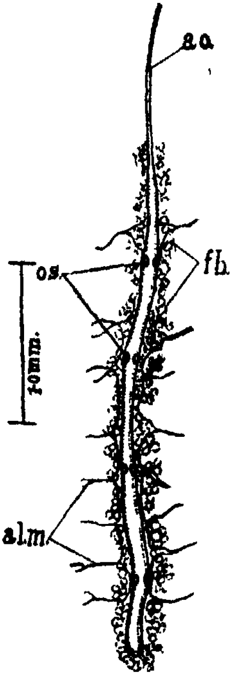


FIG 10 Dorsal vessel and aorta

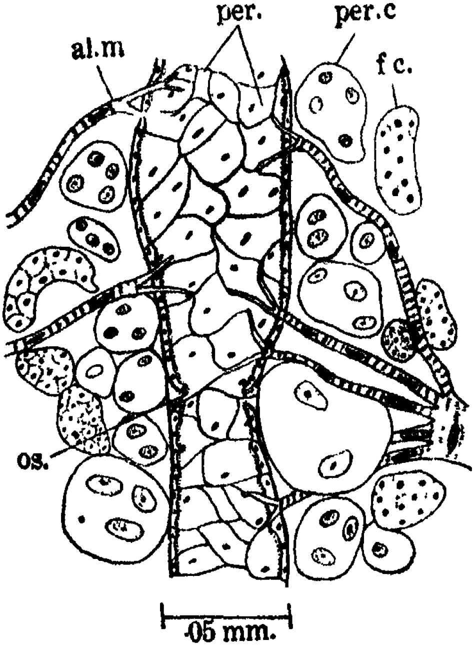


FIG. 11. Part of Heart and associated structures

Anteriorly it is continued into the aorta which opens in the head region The heart does not show any marked constrictions into chambers and is surrounded on both sides by a thick coating of fat (*f c*). It is kept in position by eight pairs of alary muscles (*al m*) and is provided with four pairs of ostia (*os*). Lying closely applied to the heart are a number of pericardial cells (*per c*) with very large nuclei. Some of the cells contain as many as four nuclei. The pericardial cells can be easily distinguished from the fat cells on account of their large vesicular nuclei and more or less homogeneous protoplasm. The adventitia (pericardium: *per.*) shows a reticular structure. The alary muscles show no striations in their terminal portions which are intimately attached to the adventitia.

V. THE TRACHEAL SYSTEM

There are two pairs of thoraric and seven pairs of abdominal spiracles. The structure of the spiracles has already been described (Khatib[14]) In naming the principal spiracular trunks the terminology given by Snodgross[30] has been followed. Viewed from the dorsal side, after a careful removal of the tergites (Fig 12), a pair of lateral longitudinal trunks (*lat long t*), one on each side of the body, connecting all spiracular tracheæ from the first thoracic to the seventh abdominal spiracle is seen From the first abdominal to the sixth abdominal spiracle each of these trunks gives off dorsally three branches in the inter-spiracular regions. From the last abdominal spiracle is given off dorsally a transverse branch which divides into four main branches supplying the posterior portion of the heart, rectum, genitalia and the fat body. The lateral longitudinal trunks as indicated above give off three main branches between the two consecutive spiracles which divide and subdivide supplying the various internal organs which lie in their region Each longitudinal trunk expands between the first abdominal and the second thoracic spiracle. The first abdominal spiracle apart from supplying the various internal organs and the body wall also gives off a large number of branches (*d musc*) from its spiracular tracheæ to the dorsal muscles of the metathorax It further gives off a second longitudinal trunk (*s long t*) which establishes connection with the spiracular trachea of the metathorax. Upto the metathorax the two lateral longitudinal trunks remain quite separate. In the anterior half of the mesothorax they are connected by a commissural trunk (*cr c m*) and by a similar commissural trunk (*cr. c p*) at the posterior border of the prothorax and at the base of the head (*cr c h.*). These commissural vessels may have arisen to provide better ventilation in the thoracic and head regions Anterior to the commissure of the head region the lateral longitudinal trunks proceed into the head as the dorsal head trunks (*d h tr.*) and divide into a number of small branches supplying the dorsal muscles of the head and the compound eyes. The main branch on either side proceeds forward to supply the antenna (*ant b*). In the region of the metathoracic and the first abdominal spiracles a number of large tracheal branches are given off which supply the highly developed muscles of the metathorax

When the dorsal tracheæ and the various internal organs are carefully removed the ventral tracheæ come to view (Fig. 13) There is a pair of ventral longitudinal trunks (*vent. l t.*), one on each side of the body, uniting the ventral spiracular tracheæ from the last abdominal to the first thoracic spiracles. Throughout their length these longitudinal trunks are connected

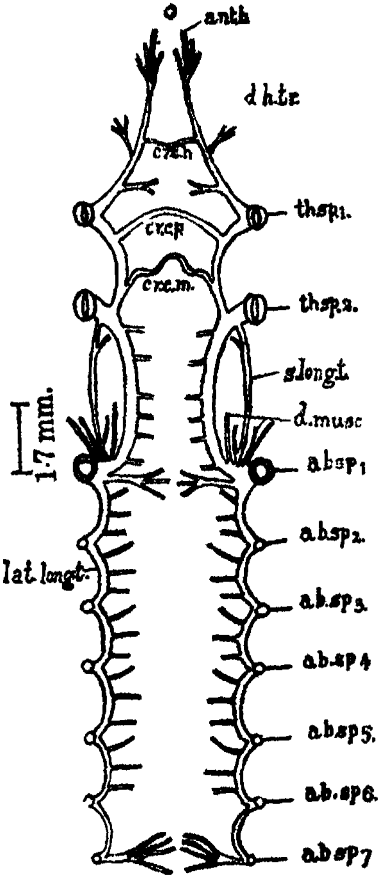


Fig. 12. Tracheal System, *Dorsal view*.

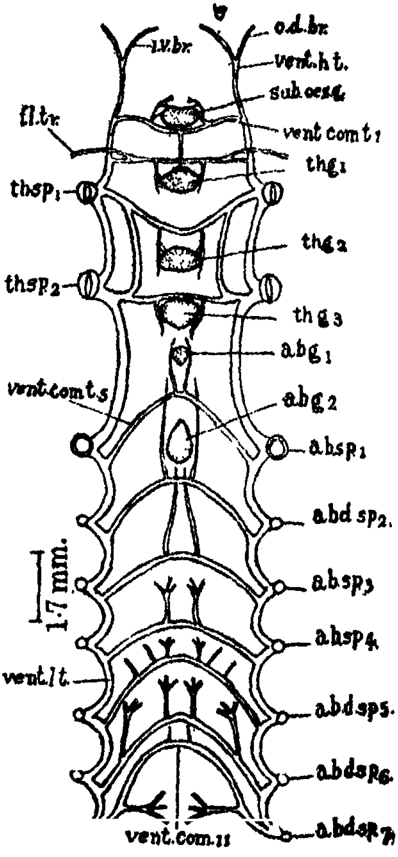


Fig. 13 Tracheal System, *Ventral view*.

with one another by ventral commissural trunks (*vent com t*). In all there are eleven such commissural trunks (*vent comm t* 1-11). The arrangement of these commissures and their relation to the ganglia of the ventral nerve cord where the latter exist are clearly shown in Fig. 13 and hence need no description.

The first leg is supplied by a branch given off from the second ventral commissural trunk (*f l. tr.*). The second leg is supplied by a branch given off from the metathoracic spiracular trunk. The hind leg receives its tracheal supply from two sources, *viz.*, the metathoraic spiracular trunk and the first abdominal spiracular trunk. These two branches anastomose in the region of the femur.

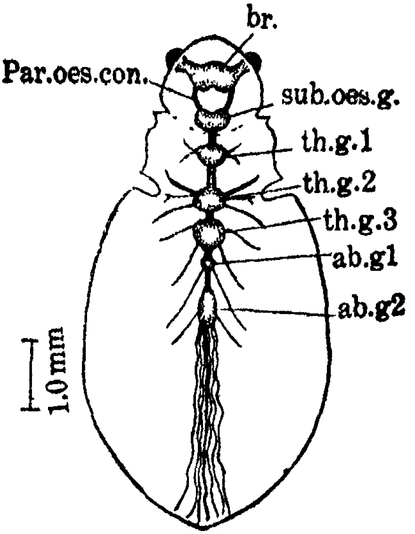
Anterior to the level of the sub-œsophageal ganglion the ventral longitudinal trunk continues as the ventral head trunk (*vent. h. t.*) After entering the head region it divides into an outer and dorsal branch (*o. d. br.*) supplying the mandible and an inner and ventral branch (*i. v. br*) which immediately splits into three branches supplying the maxilla, the hypopharynx and the labium.

As was suggested in a previous communication (Khatib[15]) the distribution of tracheæ in this beetle throws important light on the homologies of the two thoracic spiracles and to a certain extent supports the recently put forward hypothesis of Keilin.[18] The trachea of the prothoracic leg arises from the second ventral commissural trunk which lies very close to the first spiracle. In other words the first pair of spiracles supply the prothoracic legs. The mesothoracic legs are supplied by the second thoracic spiracles If, as is generally held, the two thoracic spiracles be regarded as belonging to the mesothorax and the metathorax, the mesothoracic legs aught to be supplied by the first pair of thoracic spiracles but this is not the case. The arrangement in *G. birmanica* can be explained on the assumption that a backward migration of the second pair of thoracic spiracles from its intersegmental position has taken place. Further the entire pterothorax (meso-cum metathorax) is supplied by branches from the mesothoracic and the first abdominal spiracles. The first pair of thoracic spiracles contributing no tracheæ to this region. If the first pair of thoracic spiracles definitively belong to the mesothorax and have come to be situated in the prothoracic region secondarily, one would expect that at least part of the mesothoracic tracheal supply should come from the first pair of thoracic spiracles. Hence, as suggested by Keilin one may be justified in regarding the two thoracic spiracles as belonging to the prothorax and the metathorax. The mesothorax being devoid of spiracles.

VI. THE CENTRAL NERVOUS SYSTEM

The central nervous system (Fig 14) consisting of the brain (*br.*), the sub-œsophageal ganglion (*sub. oes. g*) and the ventral nerve cord shows the greatest specialization in the abdominal region.

From the brain there proceed two slender connectives, the para-œsophageal connectives (*par oes c.*) which join the brain with the sub-œsophageal ganglion situated ventrally at the base of the head. The three



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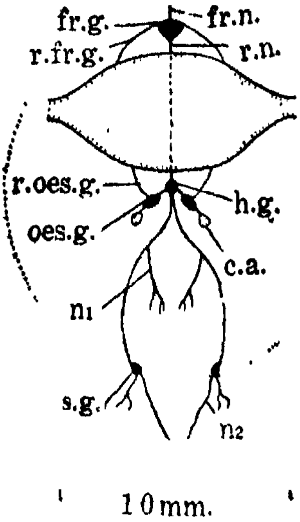

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Fig 14 Central Nervous System, *Dorsal view*

Fig 15. *Dorsal view* of the brain and the Stomatogastric nervous System

thoracic connectives of the ventral nerve cord retain their double nature as is the case in most coleoptera. The three thoracic ganglia (*th. g* 1 to *th g* 3) are distinct from one another. The metathoracic ganglion is the largest of the series. There are only two abdominal ganglia. The first abdominal ganglion (*abd g* 1) is very small and lies close to the metathoracic ganglion. The second abdominal ganglion (*abd g.* 2) is oval and much larger. From its postero-lateral region proceed a number of small nerves. A thick nerve arises from the middle of its posterior region.

VII. The Stomatogastric Nervous System

The stomatogastric or œsophageal sympathetic nervous system (Fig. 15) is typically developed and is on the saltatorial orthopteran plan. The triangular frontal ganglion (*fr. g*) is situated a short distance in front of the brain and lies above the œsophagus. Anteriorly it gives off a frontal nerve which goes to the clypeus. Posteriorly from the tip of the triangle is given off the recurrent nerve (*r n.*) which passes backwards between the ventral surface of the brain and the dorsal surface of the œsophagus and ends in the hypocerebral ganglion. The frontal ganglion is further connected by bilateral connectives (*r fr. g*) with the tritocerebrum. Connected with the hypocerebral ganglion are the paired œsophageal ganglia (*oes g.*) Each œsophageal ganglion is connected with the deutocerebrum by a slender nerve (*r oes g*) Lying very close to each of the œsophageal ganglion is the corpus allatum (*c .a*) Two stomachic ganglia (*s g*) are situated on the posterior dorsal surface of the œsophagus and are connected by the paired recurrent nerves with the hypocerebral ganglion. During its course each of these paired recurrent nerves gives off a small nerve (*n* 1) innervating the dorsal side of the œsophagus and the heart From the stomachic ganglion is given off a nerve (*n* 2) which proceeds backwards and downwards to the ventro-lateral surface of the crop.

VIII THE REPRODUCTIVE SYSTEM

1 *The Female*—The female reproductive system (Figs 16 and 17) consists of a pair of ovaries situated in the anterior abdominal region In Fig. 15 they are shown much drawn forward for the sake of clarity The position of the ovarioles in relation to the gut wall is shown in Fig 16 Each ovary consists of twelve acrotropic ovarioles provided with terminal filaments (*term f*) The terminal filaments of all the twelve ovarioles of one side combine together to form a common thread which is attached to the fat body. From each ovary is given off an oviduct (*l ov. d* and *r. ov d*), the two oviducts unite together to form the common oviduct (*med ov d*) which is

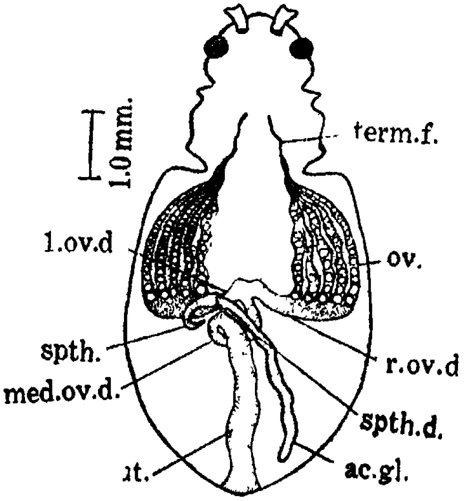

FIG. 16 Female Reproductive System, *Dorsal view*

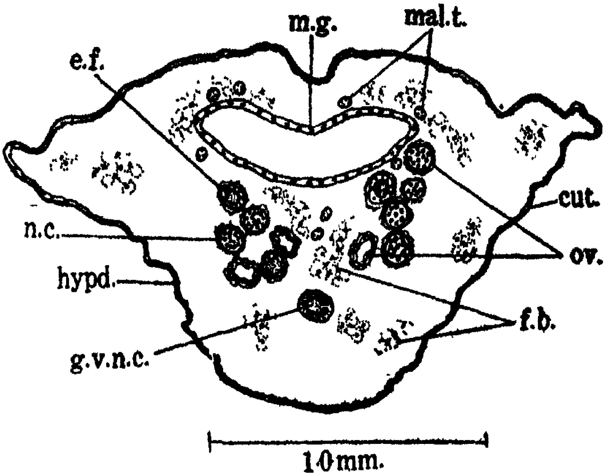

FIG 17. Transverse section of female abdomen.

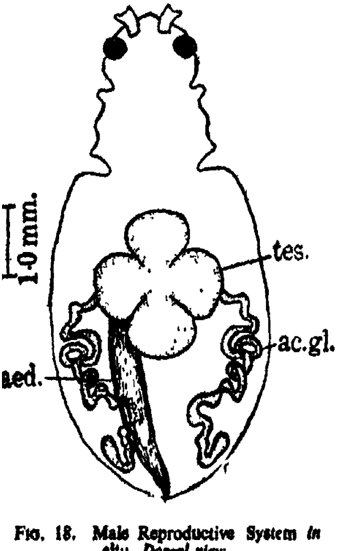

FIG. 18. Male Reproductive System *in situ*, *Dorsal view*.

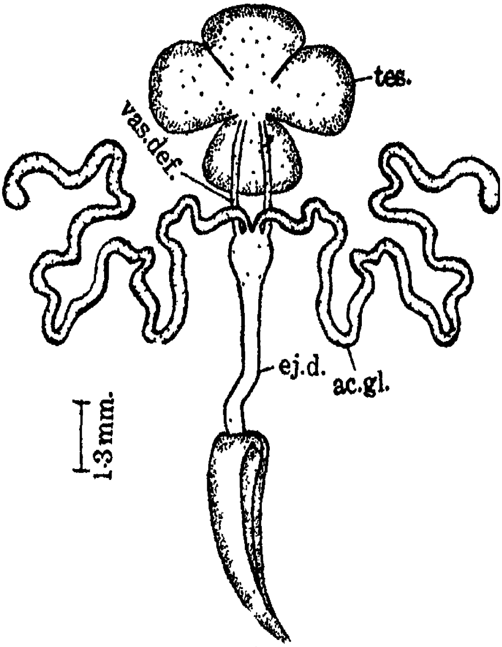

FIG. 19. Male Reproductive System, *Dorsal view*.

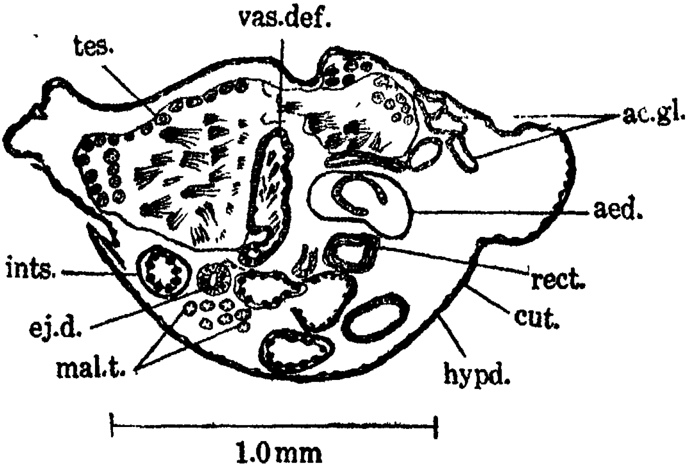

FIG 20. Transverse section of male abdomen

continuous posteriorly with a much wider and long uterus or vagina (*ut*) opening behind the ninth segment The uterus receives on its dorsal side the common duct of the spermatheca and the accessory gland.

The spermatheca (*spth.*) is a hook-shaped chitinous structure lying very close to the wall of the uterus with which it communicates by a short duct (*spth. d*) The long tubular accessory gland (*ac. g*) communicates with the duct of the spermatheca.

2. *The Male.*—The male reproductive system (Figs. 18, 19 and 20) consists of four large, oval and sessile testicular follicles (*tes*) situated dorsal to the alimentary canal in the middle of the abdominal region and communicate directly with the two *vasa deferentia* (*vas. def*). Each vas deferens is a small slender tube which extends from the testicular follicles to open into the ejacualory duct along its lateral side where the latter shows a slight dilatation The ejaculatory duct (*ej d.*) also receives a pair of much convoluted accessory glands (*ac. gl*) along its mesial surface. It then continues as a slender tube and pierces the proximal part of the ædeagus.

IX ACKNOWLEDGEMENTS

The author wishes to express his deep sense of gratitude to Professor M B. Mirza, Dean of the Faculty of Science and Head of the Department of Zoology, Muslim University, Aligarh, for his valuable guidance and the keen interest he took throughout this work. The author is also thankful to Dr M A. H Qadri for his many valuable suggestions and to Professor M A Moghe for his help in microtomy. Thanks are also due to Lieut - Col N Ganguli, Principal, College of Science, for granting the facilities of work.

X SUMMARY

1 To the best of the author's knowledge the Internal Anatomy of an Indian Galerucid beetle has not been attempted so far As a matter of fact a search through the literature reveals that so far as the anatomical studies are concerned the entire family is very much neglected

2 The arrangement of the Malpighian tubules differs in certain important respects from that described by Heymons and Luhmann in *Galerucella viburni*

3 The distribution of tracheæ in the thoracic region support the recently put forward hypothesis of Keilin with regard to the position of the two thoracic spiracles in insects

4 The stomatogastric nervous system is on the saltatorial orthopteran plan

5 There are four testicular follicles and the entire testis occupies a median position

6 The ovarioles are acrotropic and each ovary consists of twelve ovarioles.

XI. LETTERING

abd g 1	first abdominal ganglion.
abd g 2	second abdominal ganglion
ac gl	accessory gland.
aed	aedeagus.
al m	alary muscles
ant b	antennal branch
ant mal t	anterior Malpighian tubules
ao	aorta
br.	brain
ca	corpus allatum.
cc 2	common stem formed by the two posterior tubules.
cc. 3	Main stem formed by cc 2 and one anterior tubule
cir m	circular muscles.
col	colon.
com. k.	common knob
cr	crop
cr c h	commissural trunk of head.
cr. c m.	commissural trunk of mesothorax.
cr c p	commissural trunk of prothorax.
cut	cuticle.
d h tr	dorsal head trunk
d musc.	tracheal branches to dorsal head muscles
e f	egg follicle
ej d	ejaculatory duct
f b.	fat body.
f. c	fat cells
f g	fore-gut
fr g, fn n	frontal ganglion and frontal nerve.
g v n c	ganglion of ventral nerve cord.
h g	hypocerebral ganglion
hypd	hypodermis
il	ileum.
int	intima.
i v br	inner and ventral branch of head trachea.
lat long. t	lateral longitudinal trunk

lg. m.	longitudinal muscles.
l., r., ov. d.	left and right oviducts.
mal. t.	Malpighian tubules.
mal. t. 1o, 2o	openings of the first & second anterior Malpighian tubules
med. ov.	median oviduct.
mi g	midgut.
n1.	nerve supplying the dorsal surface of crop.
n2	nerve supplying the ventro-lateral surface of crop and midgut
n. c	nurse cell.
o d. br.	outer and dorsal branch of head trachea.
oes.	œsophagus.
oes. g.	œsophageal ganglion
oes. v	œsophageal valve
os	ostia.
ov.	ovary.
par oes. c	para-œsophageal connective
per	pericardium.
per. c.	pericardial cells.
per. m	peritoneal membrane
ph.	pharynx
rect.	rectum.
rect. pl	rectal plexus
r fr. g	root of frontal ganglion
r n.	recurrent nerve.
r. oes g	root of œsophageal ganglion
st s g	stomachic ganglion.
s long t	second longitudinal tracheal trunk
spth	spermatheca.
spth. d	spermathecal duct
sub oes g	sub-oesophageal ganglion
term. f	terminal filament.
tes	testis
th. g 1 to th. g 3.	first to third thoracic ganglia
vas. def	vas deferens
vent comm. t	ventral commissural trunk.
vent. h t.	ventral head trunk.
vent l. t.	ventral longitudinal tracheal trunk.

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MASTIGOCLADOPSIS JOGENSIS gen. et sp. nov., A NEW MEMBER OF THE STIGONEMATACEÆ

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(With one plate and 13 figures in the text)

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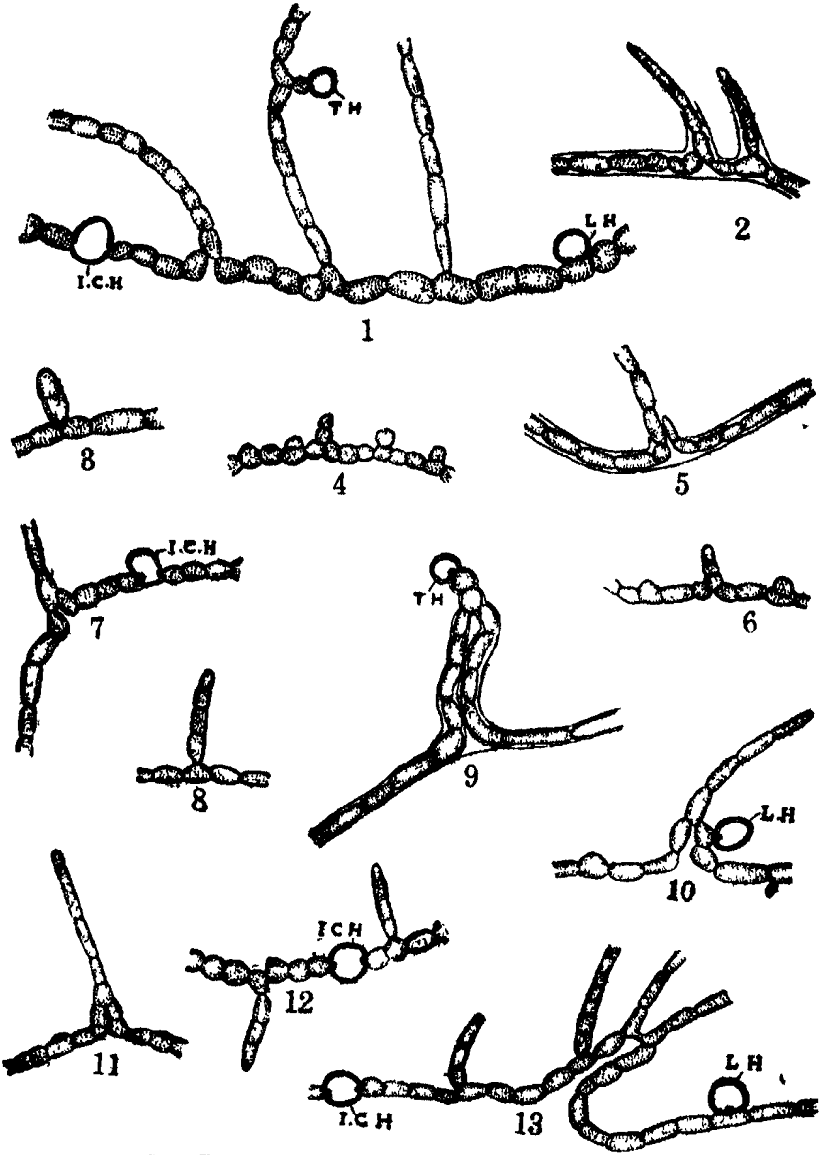
A blue-green alga, which shows many interesting features and appears to be new, was collected from a stream near Jog Falls in the Shimoga District, Mysore Province It formed tiny gelatinous expansions on submerged stones in the stream.

The plant consists of an intricate mass of main filaments from which arise a number of branches which are very long and slightly narrower than the main filaments The filaments are provided with a closely investing sheath which is thin, hyaline and unlamellated (Text-figs. 2, 5, 9) Often in the younger portions of the filaments the sheath is very indistinct The trichome is torulose in the main filaments and unconstricted or only slightly constricted at the cross walls in the branches. The cells are spherical to barrel-shaped in the main filaments and are 2·6–5 2 μ broad and 3·9–6·6 μ long. The cells in the branches are somewhat longer and cylindrical and are 2–3·9 μ broad and 6·6–14 4 μ long.

The heterocysts are intercalary, lateral or terminal. Terminal heterocysts are situated at the end of very short branches, which are 1–3 celled (Text-figs. 1, 9). Intercalary heterocysts (Text-figs 1, 7, 12 and 13) are ellipsoidal to cylindrical and are 3 9–6·6 μ broad and 5·2–10·5 μ long Terminal (Text-figs 1 and 9) and lateral heterocysts (Text-figs 1, 10 and 13, Plate I, Fig. 1) are ovate to roughly spherical in shape and are 3·9–7·2 μ broad and as long as broad or slightly longer.

Branching occurs profusely. The branches are typically mastigocladaceous and resemble very closely those of *Mastigocladus* or *Herpyzonema* They are either pronouncedly reverse 'V'-shaped (Pl. I, Figs. 1, 3; Text-figs. 9, 10, 11 and 13) or merely rest on two cells of the main filament forming a reverse 'V' (Pl. I, Fig. 2; Text-figs. 3, 4 and 7). Some of the



TEXT-FIGS. 1—13. *Mastigocladopsis jogensis* gen. et sp. nov.

FIG. 1 Portion of a well-branched filament with intercalary, lateral and terminal heterocysts.
FIGS. 2 and 5. Portions of filaments with the sheath drawn
FIGS 3, 4 and 6 Young stages of Mastigocladaceous branchings
FIGS. 7, 9, 10, 11 and 13 Well developed Mastigocladaceous branchings
FIGS 8 and 12 Portions of filaments showing branching
(All except Fig. 3 × 750, Fig 3 × 1100)
(L. H Lateral Heterocyst, T H Terminal Heterocyst, I C H Intercalary Heterocyst)

branches, however, appear like true branches and rest only on one cell of the main filament (Text-figs 8 and 12).

No hormogones or spores were observed

SYSTEMATIC POSITION

This alga, in having both lateral and terminal heterocysts, resembles the members of the Nostochopsidaceæ But it differs from them in having reverse 'V'-shaped branches which are characteristic of the members of the Mastigocladaceæ The alga is therefore very interesting in combining within itself the main characteristics of two separate families, *viz*, the Nostochopsidaceæ and the Mastigocladaceæ This fact makes it difficult to refer it to either of these two families It is therefore referred to a new genus, *Mastigocladopsis*, and placed in a new family by name Mastigocladopsidaceæ The alga itself may be called *Mastigocladopsis jogensis* sp nov The new family proposed above may be considered as a synthetic family from which both the Nostochopsidaceæ and the Mastigocladaceæ have probably been derived, or, the family may be considered to have been derived from a common ancestor from which both the Mastigocladaceæ and the Nostochopsidaceæ took their origin

In case the establishment of this new family should be objected to, the only alternative would be to place the new genus *Mastigocladopsis* along with *Nostochopsis*, *Hapalosiphon*, *Mastigocladus* and the other allied genera under one single family, Stigonemataceæ But, since the differences between the families Nostochopsidaceæ, Mastigocladaceæ and Stigonemataceæ are so distinct and characteristic, the authors feel that it would be best to keep these families quite separate as was done by Geitler (1925 and 1932) and not include all the genera belonging to these families under the one single family, the Stigonemataceæ.

Seurat and Fremy (1936) recorded from Tunisia an alga which possesses both lateral (sessile) and terminal (pedicellate) heterocysts as well as intercalary heterocysts and reverse 'V'-shaped branching. These authors refer this alga to *Hapalosiphon laminosus* Hansg ? (= *Mastigocladus laminosus*

Cohn.). Since this Tunisian alga possesses both terminal and lateral heterocysts as in the Nostochopsidaceæ and also the reverse 'V'-shaped branching characteristic of the Mastigocladaceæ, the writers feel that it must be included in the present genus, *Mastigocladopsis.*

DESCRIPTION

Family MASTIGOCLADOPSIDACEÆ

Filament sheathed and branched; branching both reverse 'V'-shaped and simple; Heterocysts intercalary, lateral and terminal.

Genus *Mastigocladopsis* gen. nov.

Filament sheathed and branched; branching both reverse 'V'-shaped and simple; trichomes with a single row of cells Heterocysts intercalary, lateral and terminal Hormogones and spores not known.

Mastigocladopsis jogensis sp nov.

Filaments flexuous; branches profuse; branching both reverse 'V'-shaped and simple; branches generally thinner than the main filaments; sheath thin, hyaline and unlamellated, trichome somewhat torulose in the main filaments and unconstricted at the cross-walls in the branches; cells barrel-shaped in the main filaments (2·6-) 3·9-5·24 μ broad and 3·9-6·6 μ long; cells in the branches cylindrical, 2-3·9 μ broad and 6·6-14·4 μ long. Heterocysts intercalary, lateral and terminal at the end of very short branches, which are 1-3 cells long; inter-calary heterocysts cylindrical or ellipsoidal, 3·9-6·6 μ broad and 5·2-10·5 μ long; lateral and terminal heterocysts spherical or ovate and 3·9-7·2 μ broad

Hab.—Growing on submerged stones in a running stream, near Jog Falls, Shimoga District, Mysore Province, S India

SUMMARY

An alga which shows the characteristics of the two families, the Nostochopsidaceæ and the Mastigocladaceæ, *viz*, both lateral and terminal heterocysts as in the former family and reverse 'V'-shaped and simple branching as in the latter family is described in detail. Owing to the combination of the characteristics of two distinct families, the alga is referred to a new genus by name *Mastigocladopsis* and placed in a new family the Mastigocladopsidaceæ.

M O P. Iyengar and T. V. Desikachary   Proc. Ind. Acad Sci., B, vol XXIV, Pl. I

Fig 1

Fig 2

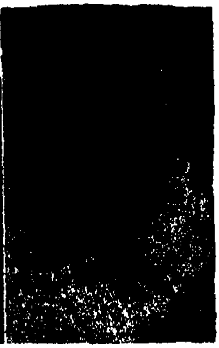


Fig 3

Figs 1-3 *Mastigocladopsis jogensis* gen et sp nov

Fig 1 —Photomicrographs showing a well developed mastigocladaceous branching and a lateral heterocyst

Figs —2 & 3 —Photomicrographs of filaments showing mastigocladaceous branchings, (all × 850)

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A PRELIMINARY RECORD OF SOME OF THE CHEMICAL AND PHYSICAL CONDITIONS IN WATERS OF THE BOMBAY HARBOUR during 1944-45

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1 Introduction

The parallelism between the variations in the occurrence of phytoplankton and the available nutrient salts has been so repeatedly established that it is now taken for a fact The chemistry and physics of sea-water and their bearing on the life in the sea have been thoroughly studied by a host of workers over a number of years The chemical constituents of biological importance in the English Channel have been worked out by Atkins[6-11], Cooper[13-16], Harvey[17], Orr[28] etc and those of Clyde sea by Marshall[26]. Rakestrav[31] has likewise studied the biology and chemistry of the Gulf of Maine, and Orr[29] the chemical and physical conditions in the sea in the neighbourhood of the Great Barrier Reef Howat[21] has recently made additions to our knowledge about the variations in the composition of the sea in West African waters In fact the importance of such a type of work has been widely recognised, as this problem is investigated in most of the Marine Biological Laboratories all over the world

The history of Oceanographic research in Indian waters dates as far back as 1875 when the survey ship "Investigator" was chartered for the Marine Survey under the leadership of Surgeon-Naturalist Alcock. The bottom deposits were studied by him, but the systematic investigation of hydrography was not commenced until 1910 In the initial stages only the air and water temperatures and salinity of sea-water were recorded. An intensive study of the physical conditions in Indian waters was made by Sewell[33] and the results of his investigation extending over several years were published in his monumental memoir on "Geographic and Oceanographic research in Indian waters" His investigation started with the study of the nature of the sea-bed and deep-sea deposits of the Andaman sea and the Bay of Bengal. A series of observations on the surface salinity and temperature of the Andaman sea, the Bay of Bengal and the Laccadive sea were made by Sewell and graphically shown in his memoir Matthews has likewise examined a large number of samples of surface sea-water brought by "Sealark" and other merchant ships from different localities of the Indian Ocean and has given a comprehensive account of his investigation in his paper on "Physical Oceanography of the Indian Ocean"[27]

Thompson[35] has however recorded some chemical constituents in the Indian waters during the John Murray Expedition, 1933–34 Recently Chidambaram and Menon[13] have correlated the occurrence of plankton and certain oceanographical factors with the fisheries of the West Coast (Malabar and South Kanara) Their investigation extends over a period of five years 1938–42 and includes only two hydrographical factors namely, the temperature and the specific gravity

It will be seen from the above resume that the study of the chemistry of the Indian Ocean has received comparatively little attention in the past and practically no work has been done on the chemical and physical conditions prevalent in Bombay waters We have therefore recently undertaken a systematic study of the chemitry of sea-water, the knowledge of which is essential in all marine and fishery research The data regarding the chemical and physical conditions of Bombay waters, when accumulated over some years, will enable us to account for the periodical fluctuations seen in our study of the local plankton, fish eggs and fish larvæ. The present paper is only a preliminary record of the chemical constitutients like silicate, phosphate, nitrite and ammonia and of a few physical factors present in Harbonr waters during 1944–45 The meteorological data is also recorded along with it

2 METHODS

A weekly analysis of a sample of surface water from the Bombay harbour was made from July 1944 to June 1945. During this period 47 samples taken from near the shore were examined and the results shown in Table I. The meteorological data for the same period was also recorded (Table II)

The temperature of water was read on a standard Centigrade thermometer immediately after taking the water sample.

Date	Time	Tem. (°C)	Density	pH	Salinity o/oo	Phosphate (Mg per M^3)	Silicate (Mg. per M^3)	Nitrate (Mg per M^3)	Ammonia (Mg. per M^3)
17—7—1944	3 P M	27·5	1015	8 1	23·56	20	1000		142
24—7—1944	3 ,,	28 5	1016	8 15	27 5	21	586 5	6 56	99
2—8—1944	3-30 ,,	29	1016	7 95	34 2	25 5	815	7 4	38·9
7—8—1944	,,	28 5	1017	8 15	24 6	27	833 3	18·3	28 2
14—8—1944	4 ,,	29	1017	8 1	30 1	26	990	23 2	30·8
21—8—1944	3-30 ,,	27 5	1016	8 15	25 1	22	960	22 4	37·7
2—9—1944	12 Noon	29	1015	8 1	27 75	25 5	930	36 0	49 9
7—9—1944	,,	29	1017	8 2	32 35	21 5	750	39 20	70
18—9—1944	3-40 P M	30	1023	8 1	359 5	23 5	344	13 6	50 5
25—9—1944	1-45 ,,	30	1021	8 15	34 35	26 5	315	45·6	85 5
2-10—1944	1-40 ,	30	1023	8 15	36 9	28 75	500	32 0	47 5
9-10—1944	3-30 ,,	29·5	1022	8·15	33 5	28	416	88	133
20-10—1944	11-30 A M.	29	1024	8 15	35 9	29 5	375	14 46	10 8
24-10—1944	,,	29 8	1023	8 3	35 6	27·3	450	16·0	13 3
2-11—1944	,	30	1024	8·15	36·5	37 8	528	14·02	11·5
6-11—1944	,,	30	1024	8 15	35 5	51 9	644	20 02	9 84
13-11—1944	11-20 ,,	29 8	1024	8 15	35 7	28 0	405	16·0	12 9
20-11—1944	11-30 ,,	28	1024	8 1	35·2	26 0	460 4	14 4	14 3
28-11—1944	12-30 P M	29	1024	7 9	36 0	21 0	1406	20 68	42 38
4-12—1944	3-30 ,,	27 5	1025	7 90	37 1	27·3	735 3	25·6	156 3
11-12—1944	11 A M	29	1025	7 85	36 0	23 7	588·2	90 31	50·58
19-12—1944	11-30 ,,	29	1025	7 8	36 5	26 0	366	15 6	49·03
25-12—1944	12-30 P M	26 8	1024	7 9	36 3	23 5	365	27 04	18 99
1—1—1945	2-30 ,,	26 8	1025	8 0	35 4	32 5	378	16·8	40 02
9—1—1945	12-30 ,,	24	1024	8 15	30 1	27 5	862	17 6	73 07
17—1—1945	12-30 ,,	25	1026	8 1	29 9	22 4	1812	17·6	60 01
23—1—1945	11-30 A.M	26	1025	8 1	34 2	20 15	1953	52 11	40·99
3—2—1945	2 P.M	26	1024	8 15	30	24·91	1338	126	73 07
17—2—1945	12 Noon	26	1025	8·1	30 4	27 83	836 8	24 3	52 52
24—2—1945	,,	26	1025	8 1	30 5	28·69	1842	69·68	84·0
28—2—1945	11-20 A M	26 9	1024	8 15	30 6	22·61	784·8	54·78	44·22
7—3—1945	11-20 ,,	25·4	1025	8·2	37 1	18·26	533 3	59·58	60·01
17—3—1945	1-45 P M	28·8	1025	8 3	30·8	27 7	470·0	78 6	39·07
24—3—1945	1-20 ,,	29 2	1025	8 3	32·3	21·5	540	45·4	42 2
31—3—1945	2-30 ,,	29 7	1024	8 3	35 2	20 0	1810	30·4	49·4
7—4—1945	1-45 ,,	28 5	1024	8·2	33 4	25	1363	124 0	44 22
14—4—1945	1-25 ,	29 4	1024	8 3	33 2	13 04	649·5	22 1	51 64
20—4—1945	1-30 ,,	30 5	1025	8·35	34	27 08	537·6	153 9	38·42
28—4—1945	2-30 ,,	30	1025	8 2	34·1	15·5	458 9	167 1	47·28
5—5—1945	12-30 ,	30 5	1025	8 15	38·3	33·7	1220·0	11 5	.
21—5—1945	1 ,,	31 0	1025	8·2	38·4	.	700·0	11·04	91
30—5—1945	11-45 A M	31·5	1025	8·25	38·3	20·8	606·0	5·06	93
9—6—1945	10-30 ,,	30 5	1025	8 15	36·2	15·1	700·0	4 60	65·5
16—6—1945	11-45 ,,	32·0	1025	8 2	35·3	13·5	845·0	5·06	64
23—6—1945	12-45 P.M.	32 5	1025	8·2	34·1	32 2	693 0	5·52	73 3
3—7—1945	11-20 A.M	27 0	1018	8·25	31·4	23 0	500	5·06	63·7
10—7—1945	11-20 ,,	26·8	1018	8·15	26·9	24·5	600	5·52	90·3

The salinity was determined by the silver nitrate titration method[18] with the necessary precautions and corrections applied to this method.

The hydrogen-ion-concentration was estimated on Helengis comparator.

TABLE I

Hydrographical Observations during 1944-45

Denige's method for phosphates as adopted by Atkins[6] was followed for the estimation of dissolved phosphates The reagents were prepared according to Florentin's formula[8] and the comparison of the colour of the standard solution with that of the sample of water to be tested was made on Hehner's tubes

Dissolved silicates were determined by the colorometric method of Dienert and Wandenbulcke. The colour, developed on the addition of reagents, was matched against a suitable standard picric acid solution[15]

The Nitrite content was estimated by Gries method as modified by Ilosvay and used by Orr[28] The Gries-Ilosvay reagent was renewed very often and to ensure accuracy of results, a suitable standard solution was made by diluting a standard solution of higher concentration just before the addition of reagents as the dilute standard solutions change their nitrite content readily The colours were compared in Hehner's tubes.

For the determination of Ammonia, 100 c c of sea-water, treated with 4 drops of a saturated solution of mercuric chloride, was brought in a separate jena glass flask The estimation was made according to Wattenberg's method[36] by use of Nessler's reagent All reagents excepting Nesseler's reagent were prepared each time ammonia was estimated Every possible precaution was taken to avoid contamination of the reagent with ammonia in the air and all bottles containing the reagents were specially fitted with 'U' tubes containing pumic salts and sulphuric acid

3 CHEMICAL AND PHYSICAL CONDITIONS

Temperature:—

The records of temperature of water are shown in Table I. The maximum temperature was 32 5° C on 23rd June, 1945 and the minimum 24° C on 9th January, 1945 The range of temperature during this period was therefore 8 5° C On comparing with the meteorological data (Table II) it was found that there was a close relation between the temperature of air and water and the maximum and minimum temperature of water fell almost with the same range as the daily maximum and minimum temperature of air.

The dry and wet-bulb thermometer readings (Table II) indicate that the evaporation of sea water is going on all the year round The rate of evaporation is influenced by the following factors —(1) Atmospheric pressure, (2) Atmospheric temperature, (3) Atmospheric humidity, (4) Atmospheric movements—Wind, and (5) Variations in salinity Sea-water evaporates

TABLE II

Meteorological Observations during 1944-45

Date	Atmospheric pressure	Dry Bulb Temp. (°F)	Wet Bulb Temp (°F)	Humidity (%)	Maximum Temp (°F)	Minimum Temp (°F)	Wind	
							Direction	Force
17—7—1944	29·683	84	78 5	89	84	79 1	WSW	12
27—7—1944	29 631	79 8	76·8	84	83·6	79 1	WSW	16
2—8—1944	29·661	79 4	77·6	92	79·8	75 0	SW	10
7—8—1944	29·771	80·1	77 8	90	86 3	79·1	WSW	8
14—8—1944	29 744	80·4	76 7	84	86·5	77 7	SSW	14
21—8—1944	29 675	78 7	76 5	90	82 1	75 7	WSW	16
3—9—1944	29·861	80·0	76 3	84	86 5	79 0	SW	6
7—9—1944	29 874	79·2	75 1	82	87 4	76 2	WNW	9
18—9—1944	29·787	79 5	76 6	87	86 5	77	W	3
25—9—1944	29 900	78 7	76 2	89	88 3	74·4	ESE	6
2-10—1944	29 807	79·4	77 2	90	88·6	77	ESE	10
9-10—1944	29·826	79·1	76·2	85	88	78	NNE	5
20-10—1944	29·882	81·5	73 0	85	96 6	79·3	NE	9
24-10—1944	29 853	80·8	77·3	85	93 8	78 9	E	3
3-11—1944	29·860	78 7	75·2	84	88 8	75 9	NE	4

Cloud	
Form	Amount
ScCu . AcAs (7) (3)	10
ScCu . AsAc 1 1 5 2	8
ScCu . As 7 3	10
ScCu . Ac 6 3	9
ScCu . Ac . Ci 2 T 1	3
Sc. Cu. As. Ns, Fb	10
Sc. Cu, AcAs 4 2	6
ScCu . Ac 3 2	5
ScCu . Ac 4 2	6
ScCu . Ac 3 3	6
ScCu . AcCs, Ci 2 2 4 1	9
ScCu . Ac 3 5	8
Sc . Ac T 1	1
ScCu 7	7
ScCu 2	2

6-11—1944	..	29·896	70·9	72·1	81
13-11—1944	..	29 847	76·8	70·7	73
20-11—1944	..	29·901	77 2	73·5	83
28-11—1944	..	29 826	77 4	73·5	82
4-12—1944	..	29 853	75·1	71 3	82
11-12—1944	..	29·921	74 6	70 8	82
18-12—1944	..	29·920	71·5	67·0	78
25-12—1944	.	29 876	72·6	67·5	76
1—1—1945	..	29·906	68 7	62·4	68
9—1—1945	.	29·957	68·7	67 2	92
17—1—1945	..	29·980	68·7	65 3	82
23—1—1945	.	29·906	70·8	66 2	78
3—2—1945	..	29·930	67 7	61 6	69
17—2—1945	..	29 884	68·5	61·5	65
24—2—1945	..	29 886	74 6	66·1	61
28—2—1945	..	29 893	73 7	64 1	57
7—3—1945	..	29·898	70·4	60 9	55
17—3—1945	..	29·911	75 5	69 8	78
24—3—1945	..	29·861	79 4	72 6	71
31—3—1945	..	29·798	81·4	78 3	57
7—4—1945	..	29·855	77·9	73·2	79
14—4—1945	..	29 910	77·9	74·6	85

80 7	73·3	N	5	ScCu 4	4
87 8	74·7	N	2	ScCu 1	1
94·1	75 4	ENE	6	Ci T	T
95·4	75·2	NE	8	Sc, Cs, Ci T 5 2	7
90 6	73·2	NE	7	Ac, Ci T 1	1
91 3	72 1	NE	9	Sc T	T
84	67	NNE	6	Clear sky	
85	70	ENE	9	Clear sky	
86 3	67 2	NNE	2	Clear sky	
80 1	61 2	N	9	ScCu 1	1
83	66·4	NNE	8	Sc T	T
89·0	67·4	ESE	7	Sc , Ac T 1	1
82·9	62·2	E	9	Clear sky	
82 7	64 4	NNE	6	Ci T	T
91·9	72	ENE	4	Ci 1	1
87·6	70·8	NE	4	Clear sky	
90 0	65·4	NE	5	Clear sky	
91 1	71 3	ENE	3	Clear sky	
103·1	76·8	NEN	4	Clear sky	
90·8	78·0	S	6	Sc, Cu Ac T 1	1
87 2	75 9	NNE	2	Cu 2	2
88 1	74 4	SE	3	Cu T	T

Date	Atmospheric pressure	Dry Bulb Temp (°F)	Wet Bulb Temp (°F)	Humidity (%)
20—4—1945 .	29·857	80·4	76·6	84
28—4—1945 ..	29·762	81·3	78·7	76
5—5—1945 ..	29 824	81 4	76 3	78
21—5—1945 ..	29 766	84·1	79·1	79
30—5—1945 ..	29·812	83·1	75·9	70
9—6—1945	29 665	84 4	80 7	84
16—6—1945 ..	29·707	82·0	79·5	89
23—6—1945 ..	29·682	78 5	76·7	92
3—7—1945 ..	29·678	82·2	77·9	82
10—7—1945 ..	29·544	79 2	77 6	93

Maximum Temp (°F)	Minimum Temp (°F)	Wind		Cloud	
		Direction	Force	Form	Amount
90 0	76 6	Calm	0	Sc T	T
90 21	79	NNW	2	Sc Cu Ac 2 T	2
90·5	78 9	NE	4	Cu Sc Ac 1 3 3	7
92·2)	82·1	SW	3	Cu Sc Ac 2 T T	2
92·1	80 2	N	3	Cu Sc Fc 2 T T	2
94 0	83·2	S	3	Cu Cu Sc Ns Ac T 1 2 4 1	8
82 6	73 9	SW	9	Cu Cu Ac Ci 1 2 5 T	8
86·7	75·3	SSE	5	Cu Sc Ac 4 2 4	10
88 1	74·4	WSW	13	Cu Sc Fu As Ac 1 4 T 2 2	9
88·1	76·2	WNW	14	Fu Ns As 2 6 2	10

more slowly than fresh water Harvey[17] has shown that the cooling of sea-water is to some extent dependent on the seasonal changes in evaporation

Salinity:—

The variations in salinity are shown in Fig 1. The maximum salinity recorded during the period under review was 38 4°/$_{oo}$ on 21st May, 1945 and the minimum 23·56°/$_{oo}$ on 17th July, 1944 The fluctuations of salinity during July-September were due to sudden influx of fresh water It increased during the succeeding months with intermitent rise and fall and reached its maximum in May 1945.

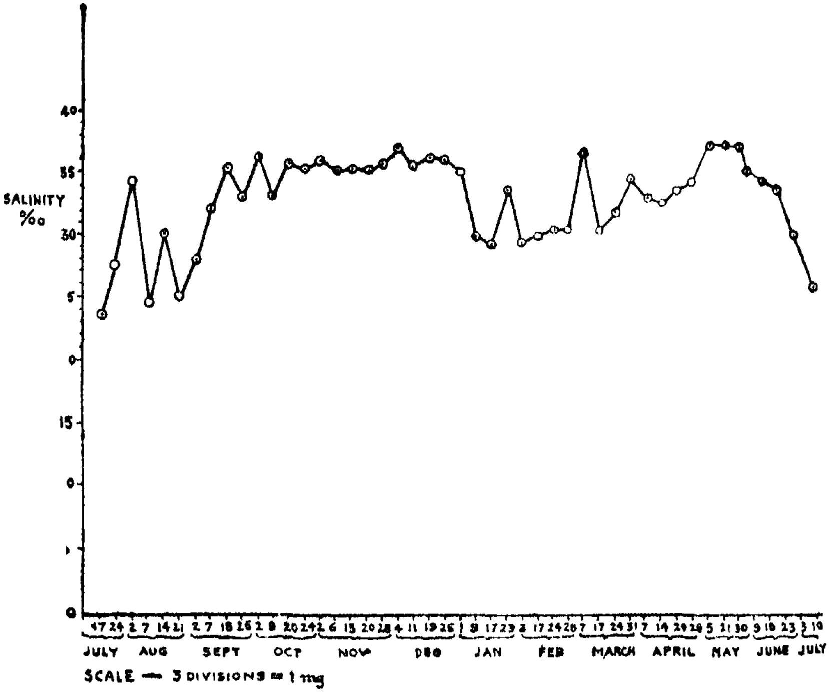

Fig. 1 Seasonal Variations in Salinity

Density:—

The variations in the density of water were in accordance with the salinity of water The maximum and minimum values recorded were 1026 and 1015 respectively (Table I).

Hydrogen-ion Concentration:—

The hydrogen-ion concentration of our harbour waters varied between 7·8 to 8·35 (Table I) It was highest on 20th April, 1945 and lowest on 19th December, 1944.

Phosphates:—

Phosphate though found in small quantity in sea-water is one of the essential food constituents of phytoplankton The phosphate content showed no marked fluctuations excepting once and was found in varying quantities throughout the year, the average being about 22 mg per m^3. It will however be seen from Fig. 2 that there was a sudden increase in the phosphate content on 6th November, 1944 Such a sudden rise has also been recorded elsewhere previously by other workers. This high value might be due to the excess of bacterial decomposition of the organic matter

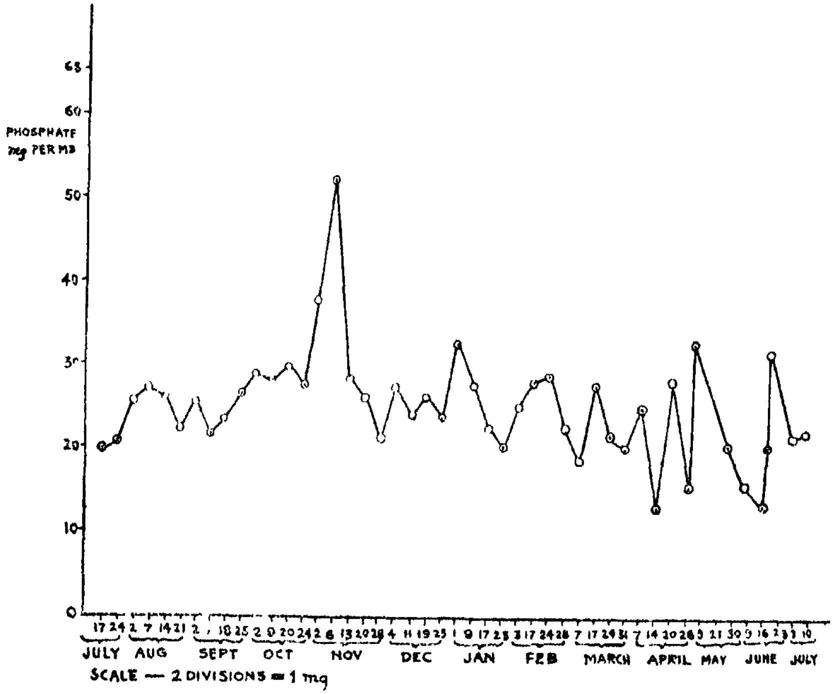

FIG. 2. Seasonal Variations in Phosphate Content

at the bottom of the sea or as suggested by Cooper[18] might be due to direct oxidation caused by a number of factors acting on the air-water interface. The lowest quantity recorded was 13·04 mg. per m^3 on 14th April, 1945 (Table I).

Silicates:—

The amount of dissolved silica in harbour waters was found to be much greater than other chemical constituents recorded here. The minimum value during this period was 315 mg per m^3 and the maximum 1953 mg. per m^3 in September 1944 and in January 1945 respectively (Fig 3) The quantity of silica was found to be higher particularly during January, February and March than the other months of the year.

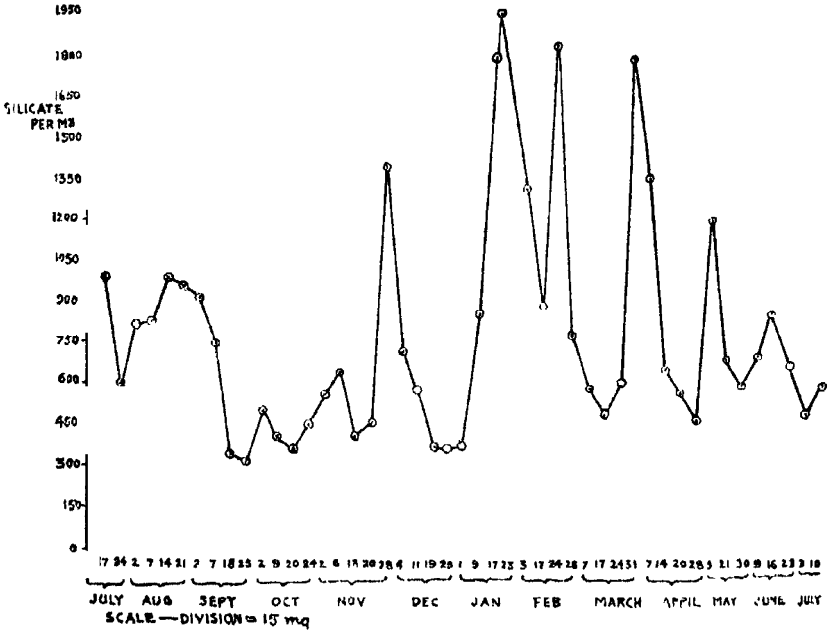

FIG 3. Seasonal Variations in Silica Content

Nitrites and Ammonia:—

The concentration of nitrite varies much as it occupies an intermediate position in the oxidation of ammonia to nitrates. The nitrite content may be taken as a useful indication of rapid transformation of ammonia to nitrates It will be seen from Fig 4 that there was in general a correspondence in the occurrence and variations of nitrite and ammonia during

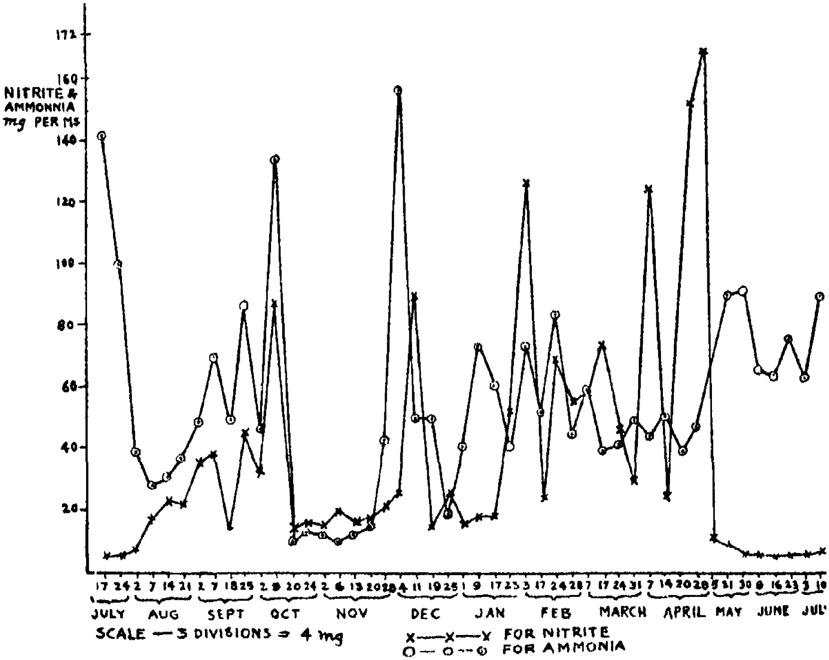

Fig 4 Seasonal Variations in Nitrite and Ammonia

this period The minimum and maximum values for nitrite were 4·60 and 167·1 mg per m^3 and for ammonia 9 84 and 156 3 mg per m^3 respectively (Table I)

Meteorological Data:—

The meteorological data such as Atmospheric Pressure, Humidity, Wind, Cloud, etc, were recorded for the same period as these factors have direct relation with the prevalent physical and chemical conditions in the sea.

4 SUMMARY OF CONDITIONS IN WATERS OF THE BOMBAY HARBOUR DURING 1944–45

(1) In the rainy season (from June 15th to the end of September) the weather was less settled and there were thunder storms and heavy showers

of rain. There was a considerable disturbance in the sea and the water was mixed over great depths during this period In the remaining part of the year the winds were lighter and the mixing of water less pronounced. The sky was overcast with clouds for the most part of the rainy season and there was a bright sun light from October to the end of May 1945

(2) The temperature of water varied between 24° C. and 32 5° C The maximum temperature of air was recorded as 103·1° F on 24th March, 1945

(3) The salinity was low in the rainy season—23 56$^\circ/_{oo}$ on 17th July, 1944 and high in the summer—38 4$^\circ/_{oo}$ on 21st May, 1945

(4) The range of Hydrogen-ion concentration was 7·8 to 8·35

(5) Phosphates were found in quantities varying between 13 04 mg /m^3 and 37 8 mg /m^3 It was as high as 51 9 mg /m^3 in one sample

(6) The amount of dissolved silica was greater than any other chemical constituents recorded here The lowest value was 315 mg /m^3 and the highest 1953 mg /m^3

(7) The minimum and maximum quantities for nitrite were 4 60 mg /m^3 and 167 1 mg /m^3 and for ammonia 9 84 mg /m^3 and 156 3 mg./m^3 respectively

5 ACKNOWLEDGEMENTS

We wish to express our grateful thanks to the Director, Colaba and Alibag Observatories, Bombay, for readily supplying us with the meteorological data recorded here To the Imperial Council of Agricultural Research, New Delhi, we are indebted for allowing us to incorporate in this paper some data, from the Council's Fishery Scheme, carried out in this department

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ERRATA

Vol. XXIII, No. 6, June 1946, Sec B

Page 266, Title of the Paper —

For "*SOALNUM*" read "*SOLANUM*".

Vol XXIV, No 1, July 1946, Sec. B

Page 28, lines 20 and 21—

For "Where there is massive parietal tissue—"

read "Where there is no massive parietal tissue—"

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FURTHER APPLICATION OF POTASSIUM FERRICYANIDE METHOD* IN THE ESTIMATION OF ORGANIC CARBON IN SOILS

By K L Khanna and S C Sen

(Central Sugarcane Research Station, Pusa, Bihar)

Received June 17, 1946

1. Introduction

The complex nature of humus which depends largely on its origin and mode of formation leads to considerable difficulties in the estimation of organic carbon in soil Further, in view of the fact that the standard dry combustion method is complicated, laborious and time-consuming, resort is being had almost entirely to the wet combustion methods by workers on soil Of these, the acid permanganate method modified by Nostitsz (1936), the alkaline permanganate method by Puri (1937) and Potassium dichromate method by Walkley and Black (1934) are in common use During the course of their work, the authors have experienced much difficulty in the application of these methods for the estimation of organic carbon in calcareous soils, which in North Bihar may contain sometimes as high as 25-30 per cent of $CaCO_3$. Under these conditions, potassium permanganate in acid medium is found to decompose on heating and thus straight away lead to erroneous results. Walkley and Black's method which perhaps surpasses all the methods referred to above in regard to simplicity and rapidity, gives invariably higher values in calcareous soils compared to the dry combustion method while Puri's alkaline permanganate method although it is the nearest approach in aggregate of the soil samples examined, gives generally lower values and its end-point is not too well-defined With the success already achieved by the authors with the alkaline potassium ferricyanide solution in the estimation of reducing sugars in cane juice (1938) and carbohydrate in cane leaves extract (1942), this solution was further tried to estimate organic carbon in soils. The results obtained during the last two seasons have compared very favourably with those obtained by the standard dry combustion method

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*The previous papers relate to the use of this method for the estimation of (i) Reducing sugars in cane juice and (ii) Carbohydrate in cane leaves.

2 EXPERIMENTAL

Potassium permanganate in acid medium decomposes on heating (Nostitsz, *loc. cit.*) and the authors find that the rate of decomposition increases with the period of boiling (Table I). Both potassium permanganate and potassium ferricyanide in alkaline medium, however, remain quite stable for the brief period of boiling which is usually not more than five minutes and is quite ample to oxidise the organic matter

TABLE I

Rate of decomposition of oxidising agents with the period of boiling

Period of boiling	(A) Acid potassium permanganate		(B) Alkaline potassium permanganate		(C) Alkaline potassium ferricyanide		Remarks
	Vol N/10 $KMnO_4$ taken	Vol N/10 $KMnO_4$ found	Vol N/10 $KMnO_4$ taken	Vol N/10 $KMnO_4$ found	Vol. $K_3Fe(CN)_6$ taken	Vol $K_3Fe(CN)_6$ found	
Just boiling	20·0	18·5	10·0	10·0	20·0	20·0	The methods used for A & B were exactly those recommended by the authors and for C as follows—20 c c of 5% $K_3Fe(CN)_6$ sol. are boiled with 20 c c. of 2·5% KOH and titrated against 0·5% extra pure dextrose sol. using one drop of 1% methyline blue as an internal indicator
	20·0	18·0	do	do	do	do	
1 minute boiling	20·0	15·1	do	do	do	do	
	20·0	14·9	do	do	do	do	
2 do do	20·0	14·8	do	do	do	do	
	20·0	14·5	do	do	do	do	
3 do do	20·0	14·0	do	do	do	do	
	20·0	13·8	do	do	do	do	
4 do do	20·0	13·6	do	do	do	do	
	20·0	13·5	do	do	do	do	
5 do do	20·0	13·0	do	do	do	do	
	20·0	12·7	do	do	do	do	

The alkaline potassium ferricyanide solution is a well-known oxidising agent and it has been observed that its rate of oxidation increases with the increased concentration of the solution. From the experimental results obtained with the various concentrations of the potassium ferricyanide as well as the KOH solutions, the following procedure has emerged as giving the best results in so far as the estimation of organic carbon in soils is concerned This consists in boiling 2 grammes of soil (finely powdered and seived through 100 mesh wire-gauze) with 20 c c. of 2·5% KOH solution for one minute, then adding 20 c c. of 5% potassium ferricyanide solution from a graduated burette, and further boiling on an electric heater for 3–4 minutes for complete oxidation The excess of ferricyanide solution is titrated back against 0·5% extra-pure glucose solution, the glucose and ferricyanide solution being standardised such that 20 c.c. of 5% ferricyanide solution exactly neutralises 20 c.c. of 0·5% extra-pure glucose solution.

Walkley and Black (*loc. cit.*) while comparing their results with those from the standard dry combustion method found that only 60–85 per cent. of carbon reacted with Potassium dichromate and therefore they multiplied their results by 1·32. Puri (*loc. cit.*) similarly worked out a constant factor of 3·9 to go with his method. This factor so far as the method outlined above is concerned is 0·2 for 2 grammes of soil, the percentage of organic carbon in soil being calculated by multiplying the volume of 5 per cent. potassium ferricyanide solution consumed by 2 grammes of soil by 0·2 (Table II). Liebig's standard method of combustion was used as the standard for comparing the results. The soil was heated in a stream of oxygen, the products of oxidation passing over glowing copper oxide to ensure complete oxidation and then overheated lead chromate to remove oxides of nitrogen, sulphur and halogens. The carbon dioxide produced was determined gravimetrically. Over a dozen soil samples in the series given in Table II contain inorganic carbon (as $CaCO_3$) and, therefore, this $CaCO_3$ was removed from the soils before actual combustion by evaporating the

TABLE II

Comparative results of organic carbon estimation by the four methods

Soil No	Particulars	Percentage of organic carbon in soils			
		Alkaline pot permanganate method (Puri)	Pot dichromate method (Walkley and Black)	Standard dry combustion method (Liebig)	Alkaline pot. ferricyanide method
1	2	3	4	5	6
1	Sepaya .	0·43	0·64	0·64	0·64
2	Mushari .	0·37	0·64	0·53	0·42
3	Motipur ..	0·29	0·64	0·47	0·48
4	Pusa ..	0·35	0·62	0·54	0·56
5	Majhaulia ..	0·41	0·47	0·39	0·30
6	Sabour ..	0·59	0·78	0·65	0·75
7	Monghyr ..	0·53	0·68	0·55	0·56
8	Harinagar ..	0·60	0·80	0·65	0·58
9	Navadah ..	0·63	0·69	0·61	0·52
10	Balasore ..	0·57	0·62	0·54	0·62
11	Tripura, Sahabad ..	1·21	1·32	1·21	1·35
12	Kanke, Ranchi ..	0·74	0·92	0·85	0·88
13	Jagadishpur, Buxar ..	0·62	0·74	0·62	0·57
14	Cuttack ..	0·57	0·77	0·66	0·80
15	Patna .	0·60	0·73	0·64	0·60
16	Patporia, Motihari	1·30	1·38	1·19	1·30
17	Kishunpore, Motihari ..	0·84	0·96	0·78	0·88
18	Bahawara, Harinagar	0·62	0·76	0·56	0·60

soil to dryness on a water-bath with excess of sulphurous acid. The soil is then powdered and mixed with a mixture of lead chromate and potassium chromate (lead chromate 1 part and potassium chromate 10 parts) in the proportion 2 1 and introduced into the combustion tube through the porcelain boat. The combustion is then proceeded as usual, only the ignition is done at a lower temperature. No sulphurous acid treatment was needed for other five carbonate-free soils

The data recorded in Table II has been subjected to statistical analysis (Table III) where the differences in between the different methods have been tested with student's '*t*' The results in the third column show that differences between A and B are highly significant whereas those between A and C and A and D are of the same order though 'D' shows closer agreement with the standard method A This would be evident from the magnitude of the intra-class correlation coefficient as recorded in column 5 of the Table III referred to above Further it has already been pointed out in para 1 above that C suffers from not too exact an end-point.

TABLE III

Statistical evaluation of different methods employed for the estimation of organic carbon in soils

(1)	(2)	(3)	(4)	(5)
	Mean	S.E	Prob (*t*)	Intra-class correln. coefficients
A–B .	−0 1229	0·0151	Less than 0 001	..
A–C ..	0·0407	0·0280	0·175	0·8720 (Bet. A & C)
A–D	−0 0107	0 0203	0·608	0·9356 (Bet. A & D)

Where A stands for the standard method
B ,, Walkley & Black's method
C ,, Puri's method.
D ,, Pot ferricyanide method

3. SUMMARY

1 Potassium permanganate in acid medium is found to decompose on heating and the rate of decomposition increases with the period of boiling.

2. A method for estimation of organic carbon in soil by oxidation with alkaline potassium ferricyanide solution is outlined.

3. The results obtained by the potassium ferricyanide method are shown to agree more closely in calcareous soils than other methods with those obtained by the standard dry combustion method. Besides the method is more exact in view of its very sharp end-point.

4 ACKNOWLEDGEMENTS

The work was carried out as part of the Sugarcane Research Scheme in Bihar partly financed by the Imperial Council of Agricultural Research to whom grateful thanks are due The assistance rendered in the analytical work by M. Farooque is appreciated

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OBSERVATIONS ON THE COLOURATION OF *MYSTACOLEUCUS OGILBII* (SYKES) DURING GROWTH

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(*Department of Fisheries, Hyderabad, Deccan*)

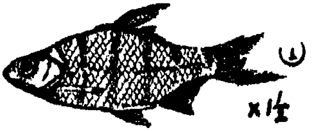
(With Text-figures 1–7)

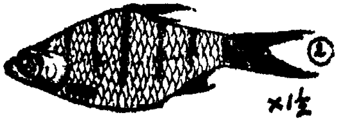
Received June 17, 1946

[Communicated by Dr M A Moghe, Ph D (London), F A.Sc]

During the fish-survey of the rivers and reservoirs of the Dominions many young stages of *Mystacoleucus ogilbii* (Sykes) were collected. Most of the specimens were caught in the River Kistna near Gadwal in the month of May 1943, since then other specimens were available from the Rivers Manjra and Godavari, and some other reservoirs. The young ones ranged from 43 mm to 97 5 mm The colouration during growth was as follows:

1. The smallest specimen (Fig 1) was 39 mm long; the ground colour in the freshly-caught specimens was yellowish-white or in some specimens brownish. Six vertical black bands were visible, 1st above the opercle 2nd a little behind it, 3rd descending from the fore-part of the dorsal fin, 4th from the posterior part of the base of the dorsal, 5th above the middle of the anal, and the 6th near the base of the caudal fin. All the bands, excepting the first two reached the ventral profile.



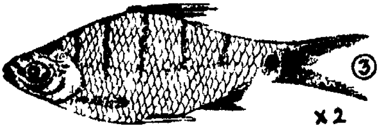


2. Specimens measuring 43 mm. (Fig. 2). Bands do not reach the ventral profile and the ground colour becomes a little lighter.

3. Specimens measuring 51 mm. (Fig. 3). Bands assume greyish-black colour and hardly distinct below the lateral line excepting the 2nd one. The last one assuming the form of a blotch.

4. Specimens 77·5 mm. long (Fig. 4). Bands become still lighter in colour and some of them split up in the middle, the lower portions assume the form of blotches. The colour of the bands becomes still lighter and the ground colour becomes silver-grey.

5. Specimens 86 mm. in length (Fig. 5). Most of the bands scatter and assume the form of irregular blotches and streaks Caudal spot still distinct.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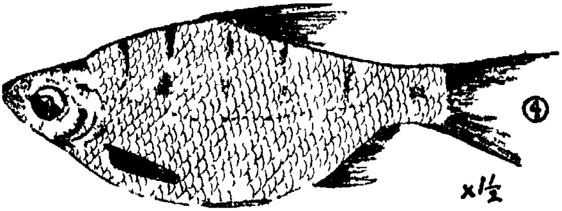
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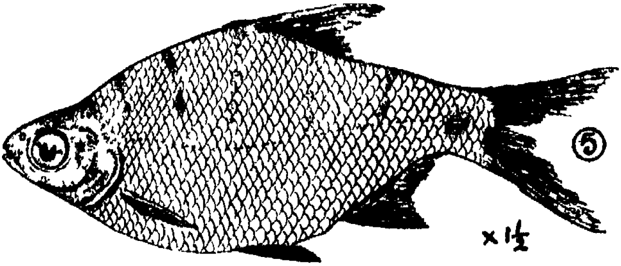
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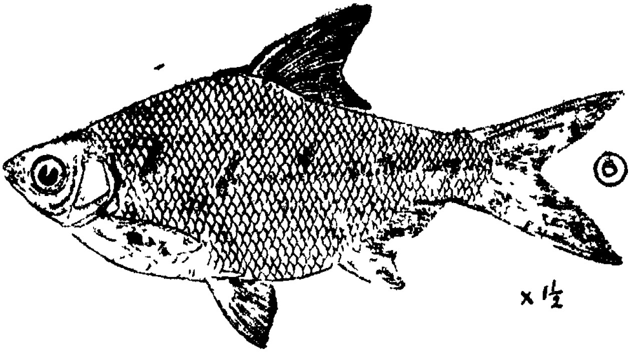
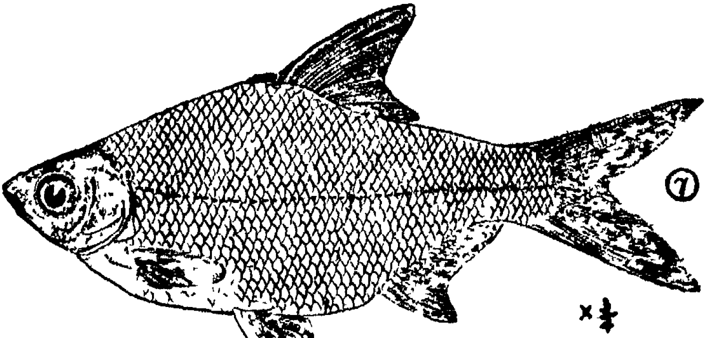
6. Specimens 97·5 mm in length (Fig. 6). Streaks irregular and found mostly on the lateral line. This stage corresponds to the specimen



described by Dr. Hora, in the *Rec. Ind. Mus.*, Vol XXXIX, Part IV, 1937, from River Tungabhadra near Kurnool

7 Fig 7 has been reproduced from Day's *Fishes of India* (Plates). He has described the colouration of the adult fish " Purplish-silvery along the back, becoming silvery-white from about four rows of scales above the lateral line The young sometimes have a dark spot at the base of the caudal fin, and four or five narrow black bands descending from the back to the middle of the side." I have no specimens in my collection which corresponds to the adult one described by Day For confirmation, I got some specimens from Dr. Suter, Poona, but could not find any in those also which were without any blotches and streaks



Mystacoleucus was included in the genus *Rohtee* by Day, but has since then been established as a separate genus, owing to the presence of "Procumbent Pre-dorsal spine" in the dorsal fin which is absent in the genus *Rohtee*. It has been fully dealt with by Mukerjee, *Rec Ind Mus*, Vol. XXXIV, 1932, and later by Dr Hora in the same Journal, Vol XXXIX, 1937.

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A SYSTEMATIC ACCOUNT OF THE MARINE PLANKTON DIATOMS OF THE MADRAS COAST

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Received June 24, 1946

(Communicated by Prof M O P Iyengar)

Introduction

Very little work has been done on the marine plankton Diatoms of the Indian coast, the only previous record being a reference to a few forms by Sankara Menon (1931) and a list of Diatoms collected from the Madras coast by Gopala Iyer, Sankara Menon and M G K Menon (1936). M A S Menon (1945) in a paper on the plankton of the Trivandrum coast has given a list of 41 Diatoms as occurring in the area As it was thought that a detailed illustrated systematic account of Indian marine Diatoms would be very useful to algologists in general and pisciculturists in particular, the author, at the kind suggestion of Professor M O P Iyengar, took up the examination of the plankton Diatoms of the Madras coast

Most of the forms dealt with in this paper was collected by the author The author is very much indebted to Professor R Gopala Iyer for placing at his disposal samples of plankton collections from the Madras coast The material, as far as possible, was examined soon after collection in the living condition and drawings were made mostly from living specimens Drawings were also made from carefully prepared slides of the forms whenever necessary For this purpose the material was cleaned, dehydrated and mounted in styrax or Canada balsam

Altogether 171 forms were recorded, representing 15 families, 64 genera, 134 species, 9 new species, 17 varieties, 4 new varieties and 7 forms

The forms showed a good deal of resemblance to those of the Java Sea (Allen and Cupp, 1935) About 50% of the forms recorded in the Madras plankton were found in the plankton of the Java Sea also But only a few of the forms recorded by Karsten (1907) from the Indian Ocean were found in the Madras plankton Many of the forms described here have been recorded previously from European waters but are new records for this country.

PART I

Bacillariophyta (*Diatomeae*)

Order: CENTRALES

Sub-order: DISCOIDEAE

Family Coscinodisceæ

Sub-family Melosirineæ

I Genus *Melosira* Agardh

Sub-genus *Paralia*

1 *Melosira sulcata* (Ehrenberg) Kützing

(Figs. 1 and 2)

Kützing, *Sp Alg*., 1849, p. 30; Pritchard, *Hist. Inf*, 1861, p 819, Pl. IX, fig. 131, Pl XI, fig. 26, Rabenhorst, *Fl Eu Alg*., 1864, pt. 1, p. 42; Van Heurck, *Traité des Diatomées*, 1899, p 444, text-fig. 166, Pl. 19, fig. 624; Boyer, *Syn. N Am. Diat*, part 1, 1926, p 25; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 276, fig. 119

Orthosira marina W Smith, *Syn. Brit. Diat*, Vol. II, 1856, p 59, Pl LIII, fig. 338

Paralia sulcata Cleve, *Diat. Artic Sea*, 1873 *b*, p 7, De Toni, *Syll Alg*, Vol. II, 1891–94, p. 1349; Allen and Cupp, *Plank Diat. Java Sea*, 1935, p. 113, fig. 1.

Paralia sulcata (Ehrenberg) Gran, *Nordisches Plankton, Bot. Teil*, Bd. VIII, 1908, p. XIX 14, fig. 5; Lebour, *Plankt. Diat N. Seas*, 1930, p. 28, fig 9.

Cells forming closely fitting, long chains, disc-shaped 11–30μ in diameter and 5-8μ in height. Valves bowl-shaped, with short mantel, at the base constricted Disc flat. Cell-wall strong Papilla-like structures at the border of the valve; those of the neighbouring cell fitting into the depression between these papillæ, and thus helping the cells to hold together. Mantel with projections Ground membrane of valve mantel with rows of pores, pores about 18 in 10μ. Outer wall of mantel drawn into lamella-like teeth. Chromatophores numerous, small, disc-shaped.

According to Grunow (*cf.* Hustedt, 1930 *b*, p. 278) the following forms are distinguishable.—

Forma *radiata*. In valve view, the middle field with a corona of slender ribs enclosing a small central area (Fig. 4).

Forma *coronata*. In the valve view, the middle field with a marginal ring of large spots (Fig. 3).

Distribution.—Northern seas, Arctic Ocean, Atlantic and Pacific coasts of America, Mediterranean Sea, Java Sea, in fossils from Greece, Sicily and Africa.

II. Genus *Podosira* Ehrenberg

2 *Podosira Montagnei* Kutzing

(Figs. 5, 6 and 10)

Kützing, *Sp. Alg*, 1849, p 26; W Smith, *Syn Brit Diat*, Vol. II, 1856, p. 53, Pl. XLIX, fig 326; Pritchard, *Hist Inf*, 1861, p 815, Pl V, fig 61; Rabenhorst, *Fl. Eu Alg*, 1864, pt. 1, p. 37, Cleve et Grunow, *Arct Diat*, 1889, p 118; De Toni, *Syll Alg*, 1891-94, Vol II, p 1360, Boyer, *Syn N Am Diat*, part 1, 1926, p. 31; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 281, fig 122.

Podosira lævis Gregory, Greville, *Descrip New sp. Diat.*, 1859 *a*, p 85, Pl. VI, figs. 15-17.

Melosira Montagnei Lagerstedt, *Saltvattens Diat*, 1876, p 9

Cells round to cylindrical with weakly developed valve-mantel and convex disc, 26-41 μ in diameter. Cell-wall areolated, areolæ in pervalar as well as in two series crossing one another, 20-24 in 10 μ In valve view, on the disc the areolæ in regular bundles parallel radial series and in irregular excentric series crossing one another Centre of the disc not differentiated, umbilicus absent. Auxospores observed occasionally.

Distribution—Littoral regions of Europe, the Caspian Sea and the Atlantic Ocean.

III. Genus *Pyxidicula* Ehrenberg

3. *Pyxidicula minuta* Grunow

(Fig. 11)

De Toni, *Syll. Alg*, Vol. II, 1891-94, p. 1148; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930 *b*, p. 301, fig. 139.

Cells very small, 13 μ in diameter. Areolæ on disc arranged in two linear system crossing one another, about 9 in 10 μ.

Distribution.—Franz Josef's Land.

IV Genus *Stephanopyxis* Ehrenberg

4. *Stephanopyxis turris* (Grev. et Arn.) Ralfs

(Fig. 16)

Pritchard, *Hist. Inf*, 1861, p. 304, Pl. V, fig 74, Castracane, *Diat. Chall*, 1873-76, p. 88; De Toni, *Syll*, *Alg*, Vol II, 1891-94, p 1138; Van Heurck, *Traité des Diatomées*, 1899, p 434; Gran, *Nordisches Plank*, *Bot. Tell*, Bd VIII, 1908, p XIX 14, fig 6, Boyer, *Syn N Am Diat*, part 1, 1926, p 35; Lebour, *Plank Diat N Seas*, 1930, p. 73, fig 46; Hustdet, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930, p 304, fig 140

Cresswellia turgida Greville. *Diat Cal Guano*, 1859 *b*, p 165, Pl. VIII, fig 14 [*Stephanopyxis turgida* (Grev) Ralfs, Pritchard, *Hist Inf*, 1861, p 826]

Cells cylindrical, with arched end faces, about 51 μ in diameter. Areolæ about 4-6 in 10 μ, all of about the same size. A number of processes arranged in a circle at the ends of the valves, those of the neighbouring cell ouching these and forming a chain

Distribution—Pelagic in the European seas, Atlantic and Pacific coasts of America; in the guano deposits of Peru

5 *Stephanopyxis Palmeriana* (Greville) Grunow.

(Figs 12-14, 17, 18 and 20)

De Toni, *Syll Alg*, Vol II, 1891-94, p 1141, Lebour, *Plank. Diat. N Seas*, 1930, p 74, fig 47; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930, p 308, fig. 147, Allen and Cupp, *Plank Diat Java. Sea*, 1935, p 113, figs 2, 2*a*, 2*b*

Creswellia Palmeriana Greville, *Descrip New and Rare Diat.*, Ser. xiv, 1865 *a*, p 2. Pl I, fig 9;

Stephanopyxis campana Castracane, *Diat Chall Expedn*, 1876, p. 88, Pl XIX, fig 14

Cells cylindrical with slightly convex valves, number of cells joined together by their spines to form chains, diameter 53-112 μ. Areolæ at the base of valve-mantel small, 7 in 10 μ; towards the disc increase in size, 4 in 10 μ and in the centre of the disc very large and hardly visible. Spines numerous, arranged in a ring and enlarged at the base.

Resting spores with very thick walls were very common During their formation, the mother-cell divides into two. Instead of normal valves being secreted, the new valves that are formed are very thick walled, strongly sculptured and more convex than the normal valves. They possess fewer spines. After the formation of this wall, the cytoplasm contracts from the other side, *i.e.*, the side towards one of the parent valves, and a similar thick-walled valve is formed. The spore in its mature condition is lens-shaped, shows a large number of chromatophores and a nucleus, and stains very densely

Distribution —Almost absent in Northern Europe, but sparsely distributed in the Southern European coast, abundant in the warmer seas, Hong Kong, Java, Australia

Sub-family Sceletonemineæ

V Genus *Sceletonema* Greville

6 *Sceletonema costatum* (Greville) Cleve

(Figs. 7, 8 and 9)

Cleve, *Diat West Ind Arch*, 1878, p 18; Van Heurck, *Traité des Diatomées*, 1899, p 437, Pl XXXIII, fig 889 and 890, Gran *Nord Plank*, *Bot. Teil*, Bd 8, 1908, p XIX 15, fig 7, Boyer, *Syn N Am Diat*, 1926, p. 63; Lebour, *Plank Diat N Seas*, 1930, Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, p 311, fig 149; Allen and Cupp, *Plank Diat*, *Java Sea*, 1930, p 113, fig 3

Melosira costata Greville, *Descrip New and Rare Diat*, 1866, Ser xix, p. 77, Pl. VIII, figs 3-6.

Frustules weakly silicified, lens shaped with rounded ends forming long slender straight chains with the aid of marginal spines which run parallel to the axis of the chain Space between the cells longer than the cells Chromatophores two plates which are at times dissected No visible structure on the valve Diameter of cells 10–15μ Auxospores were observed

Distribution —One of the commonest pelagic marine diatom, neritic, occurring in quantities Found in the Arctics as well as in the Tropics.

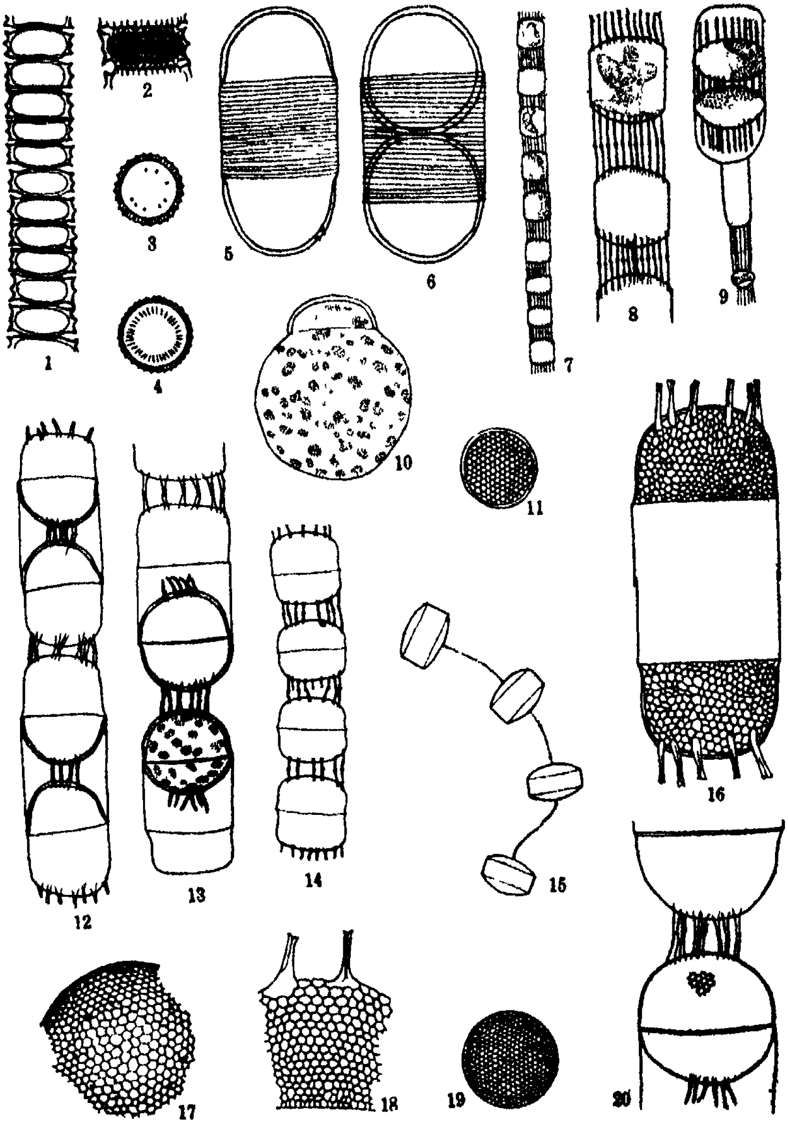
VI Genus *Thalassiosira* Cleve

7. *Thalassiosira decipiens* (Grunow) Jörgenson

(Fig 19)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, 1864, Bd VII, Teil 1, p 322, fig. 158.

Coscinodiscus decipiens Grunow, Van Heurck, *Traité des Diatomées*, 1899, p 532, Pl XXXIV, fig. 905



TEXT-FIGS 1-20.—Figs. 1-2. *Melosira sulcata* (Ehrenberg) Kützing. ×710. Fig. 3. *Melosira sulcata* f. *coronata*. × 930. Fig. 4. *Melosira sulcata* f. *radiata*. × 930 Figs. 5-6. *Podosira*

Montagnei Kützing. × 710. Figs 7–9. *Sceletonema costatum* (Greville) Cleve Fig 7, × 350; 8, × 710; 9, auxospore, × 710 Fig 10. *Podosira Montagnei* Kützing Auxospore × 710. Fig. 11. *Pyxidicula minuta* Grunow × 930 Figs 12–14 *Stephanopyxis Palmeriana* (Greville) Grunow. Figs 12 and 13 Stages in resting spore formation × 215 Fig 14 A chain of four vegetative cells. × 138 Fig 15 *Thallassiosira coramandelina* sp nov × 220 Fig 16 *Stephanopyxis turris* (Greville *et* Arn) Ralfs × 460 Figs 17–18 *Stephanopyxis Palmeriana* (Greville) Grunow. Sculpturing on the valve Fig 17, Valve view × 460, 18, Girdle view × 710 Fig. 19 *Thallassiosira decipiens* (Grunow) Jorgenson Valve view × 930 Fig 20 *Stephanopyxis Palmeriana* (Greville) Grunow Resting spore × 460

Cells disc-shaped, diameter 16 μ Valves flat with minute spines along the border. Valve areolated, areolæ in three or more systems, their size becoming smaller towards the border In the centre, about 12 in 10 μ and towards the border, 15 in 10 μ.

Distribution.—In the coastal plankton of the whole of Europe, preponderating in the North, recorded also in the Mediterranean, the Aral Sea and the Caspian Sea.

8. *Thalassiosira coramandeliana* sp nov

(Fig. 15)

Cells disc-shaped, connected by a thin mucilage strand and forming chains of 4 to 8 or rarely more. Valves convex, about 40 μ in diameter; very weakly silicified Structure on valve not visible in water mounts, the cells break down when treated for balsam or styrax mounts

This form resembles *T. Nordenskioldii* (Cleve, 1873 *b*, p 7, Pl I, fig 1; Hustedt, 1930 *b*, p 321, fig 157) and *T. decipiens* (Hustedt, 1930 *b*, p 322, fig. 158) in habit But the valve in the present form is convex unlike in the above forms where it is flat. The cells resemble those of *T subtilis* (*cf.* Hustedt, 1930 *b*, p. 330, fig. 166), but differ in their habit *T. subtilis* forms colonies by the cells being embedded in a common mucilage, whereas in the present form the cells are connected by a mucilage strand as in the first two forms

Distribution.—Plankton of the Madras coast

9 *Thalassiosira subtilis* (Ostenfeld) Gran

(Figs 21, 22 and 23)

Gran, *Nord. Plank* , *Bot. Teil*, Bd. VIII, p. XIX 19, fig. 14; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930, p. 330, fig. 166.

Cells disc-shaped, forming a colony enclosed in mucilage, diameter 36·5 μ. Valves weakly silicified, structure not visible. Chromatophores numerous, disc-shaped.

Distribution.—North Atlantic.

Sub-family Coscinodiscineæ

VII Genus *Cyclotella* Kutzing

10. *Cyclotella Meneghiniana* Kutzing

(Figs 25, 26 and 27)

Kutzing, *Sp Alg*, 1849, p. 19, Rabenhorst, *Fl. Eu Alg*, 1864, pt. 1, p 33; De Toni, *Syll Alg*, Vol II, 1891–94, p 1354, Van Heurck, *Traité des Diatomées*, 1899, p 447, Pl XXII, fig 656; Boyer, *Syn N Am. Diat*, 1926, p 38, Hustedt, Pascher's *Susswasser-Fl*, 1930 *a*, Heft 10, p 100, fig 67; Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930, p 341, fig 174; Venkataraman, *S I Diat*, 1939, p 299, figs 11, 14, Iyengar and Subrahmanyan, *Fossil Diat*, 1943, p 226, figs 1–2

Cyclotella rectangula Bribisson, Pritchard, *Hist Inf*, 1861, p 811 and 938, Pl V, fig 54

Distribution – Littoral form, coast of entire Europe; occurs in water of all concentrations,—fresh, brackish, and marine Recorded from N. America, India, fossils from Germany, Lower Austria, Italy, Moravia, Sumatra, Karewa Beds of Kashmir in India.

11 *Cyclotella striata* (Kutzing) Grunow

(Fig. 31)

Cleve and Grunow, *Arctic Diat*, 1880, (2), p 119; De Toni, *Syll. Alg*, Vol II, 1891–94, p 1352, Van Heurck, *Traité des Diatomées*, 1899, p 444, Pl XXII, fig 651, Boyer, *Syn. N Am Diat.*, 1926, p 37, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil, I, 1930, p 344, fig 176

Cyclotella Dallassiana W Smith, *Syn Brit Diat*, Vol II, 1856, p 87; Rabenhorst, *Fl Eu Alg*, 1864, p 33.

Cyclotella stylorum Brightwell, *Rarer and Undescrib Sp. Diat.*, Part 2, 1860, p 96, Pl VI, fig 16

Cyclotella radiata Brightwell, *Rarer and Undescrib Sp Diat*, Part 2, 1860, Pl VI, fig 11

Cyclotella sinensis Ralfs, Pritchard's *Hist Infusoria*, 1861, p 812, Pl XV, fig 4.

Cells disc-shaped, 16·5–35 5μ in diameter. Valves with more or less broad evenly striated border, striæ 10–12 in 10μ. Central portion with reflexes and coarsely punctate.

Distribution.—Littoral form in the European coast; estuaries along the Atlantic coast.

VIII Genus *Coscinodiscus* Ehrenberg

Section Lineati

12 *Coscinodiscus excentricus* Ehrenberg

(Figs 29 and 30)

W Smith, *Syn Brit. Diat*, Vol I 1853, p 23, Pl III, fig 38, Rattray, *Revis Coscinodiscus*, 1888-89, p 461, De Toni, *Syll Alg*, Vol II, 1891-94, p. 1210, Van Heurck, *Traité des Diatomées*, 1899, p 531 Pl XXIII fig 666, Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 29, fig 29, Boyer, *Syn N Am Diat*, 1926, p 43, Lebour, *Plank Diat N Seas*, 1930, p. 36, fig. 13, Hustedt, Rabenhorst *Kryptogamen-Fl*, Bd VII, Teil 1, 1930, p 388, fig 201, Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 114, fig 5

Coscinodiscus labyrinthus Roper, *Brit Mar Diat* 1858, p 21, Pl III, fig 2

Cells disc-shaped, valves flat in the centre, slightly drawn in with spinulæ at the margin, diameter 36 103 μ Cells hyaline, not coloured in dry preparations Sculpture hexagonal, areolæ arranged in tangential series, areolæ almost all of same size, 6 in 10 μ, at the edge, about 9 in 10 μ Margin striated Girdle also areolate, areolæ very fine and arranged regularly Valve margin striated, striæ 18 20 in 10 μ Girdle areolate-punctate, punctæ in regular rows, 18 in 10 μ

Coscinodiscus excentricus Ehrenberg var *fasciculata* Hustedt

Hustedt, Rabenhorst's *Kryptogamen-Fl* Bd VII, Teil 1, 1930, p 390, fig 202.

(Figs 32 and 38)

C subtilis Ehrenberg, De Toni, *Syll Alg*, Vol II, 1891-94, p 1232; Van Heurck, *Traité des Diatomées*, 1899, p 527, Boyer, *Syn N Am Diat*, 1926, p 50, Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 121, fig 18.

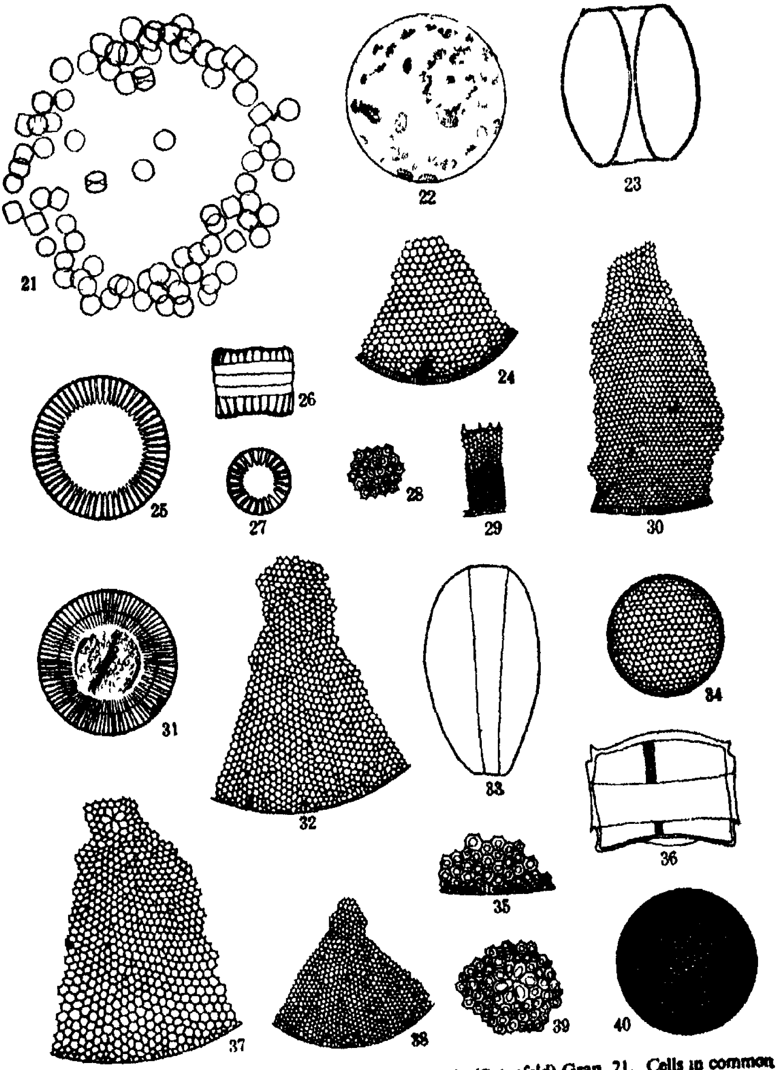
Cells disc-shaped, diameter 38-76 μ Valve areolated, areolæ in several tangential series, and, because of this, appearing as though in radial bundles Number of areolæ at the centre 9 in 10 μ and at the border 12 in 10 μ

Distribution --Both the type and the variety are met with in the plankton of most seas, frequent Europe, the Atlantic and the Pacific coasts of America, Java, Miocene deposits

13. *Coscinodiscus lineatus* Ehrenberg

(Figs. 24 and 28)

Rattray, *Revis, Coscinodiscus*, 1888-89, p 472, De Toni, *Syll. Alg*, Vol. II, 1891-94, p. 1216, Boyer, *Syn N. Am. Diat*, 1926, p. 44; Lebour,



Text-Figs. 21–40.—Figs. 21–23 *Thallassiosira subtilis* (Ostenfeld) Gran 21. Cells in common mucilage. ×148, Fig. 22. Cell, valve view ×710; Fig. 23 Girdle view, 2-daughter cells. × 710. Fig. 24 *Coscinodiscus lineatus* Ehrenberg × 710 Figs. 25–27. *Cyclotella Mene-*

ghiniana **Kützing. × 930. Figs 25 and 27, valve view, 26, Girdle view Fig 28 *Coscinodiscus lineatus* Ehrenberg × 930 Figs 29–30 *C excentricus* Ehrenberg × 930 Fig 29, Girdle view, Fig. 30, valve view. Fig 31 *Cyclotella striata* (Kützing) Grunow × 730 Fig 32, *Coscinodiscus excentricus* var *fasciculata* Hustedt × 930 Fig 33 *Coscinodiscus Granii* Gough. Girdle view. × 220 Fig. 34 *C sub-lineatus* Grunow × 930 Fig 35 *C Granii* Gough. Margin of the valve × 710 Fig 36 *C Rothii* (Ehrenberg) Grunow var *subsalsa* (Juhlin-Dannfeldt) Hustedt × 770 Girdle view Fig 37 *C Granii* var *aralensis* (Osterfeld) Hustedt × 460 Fig 38 *C excentricus* var *fasciculata* Hustedt × 710 Fig 39 *C Granii* Gough. Rosette × 710 Fig 40 *C Rothii* var *subsalsa* (Juhlin-Dannfeldt) Hustedt × 770**

***Plank Diat. N Seas*, 1930, p. 37, fig. 14, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 392, fig 204, Allen and Cupp, *Plank Diat. Java Sea*, 1935, p. 115, fig. 6

Cells disc-shaped with almost flat or slightly concave or convex valves, diameter 56 μ. Valve surface areolated, areolæ of almost the same size, 6 in 10 μ, but very near the rim 9 in 10 μ Areolæ arranged in straight line systems. Chamber openings clear Valve margin striated, striæ 12 in 10 μ.

Distribution—In all the seas, neritic and oceanic. Europe, Campechi Bay, Florida, Vera Cruz, the Pacific coast of America, and Java. A common form in all fossils (*cf* De Toni, 1891–94, p 1216–17).

14 *Coscinodiscus sub-lineatus* Grunow

(Fig 34)

Rattray, *Revis Coscinodiscus*, 1888-89, p. 474; De Toni, *Syll Alg.*, Vol. II., 1891–94, p. 1217; Boyer, *Syn N Am. Diat*, 1926, p. 44; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 394, fig 205

Valves with straight tangential series of hexagonal areoleæ Diameter of cell about 23 μ Areolæ 9 in 10 μ and 12 in 10 μ near the margin

Distribution.—So far known only from Franz Josef's Land, White Sea and Behring Sea.

Section Fasciculati

15 *Coscinodiscus Rothii* (Ehrenberg) Grunow,

var *subsalsa* (Juhlin-Dannfelt) Hustedt

(Figs. 36 and 40)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 402, fig. 212.

Coscinodiscus subsalsus Juhlin-Dannfelt, Rattray, ***Revis. Coscinodiscus***, 1888–89, p. 593; De Toni, *Syll. Alg*, Vol II, 1891–94, p. 1298.

Coscinodiscus subtilis var. ***Rothii*** (Grunow), Van Heurck, ***Traité des Diatomées***, 1899, p. 533.

Cells small, diameter 29–53 μ. Valve areolated, areolæ 10 in 10 μ, arranged more or less in bundles, but not very clear Marginal spines present. Margin broad. Cells dark under the microscope

This form slightly differs from the type. The valve views are very similar In girdle view, the valves are convex at the centre and slightly concave towards the border The difference does not appear to be sufficient enough to separate this from the type

Distribution —Common in brackish water and river mouths

Section Radiati

16 *Coscinodiscus marginatus* Ehrenberg

(Fig 41)

Rattray, *Revis Coscinodiscus* 1888-89, p 509, De Toni, *Syll Alg.* Vol II, 1891-94, p. 1241; Van Heurck, *Traité des Diatomées*, 1899, p 527, Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 35, fig 36, Boyer, *Syn N Am Diat*, 1926, p 54, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 416, fig 223, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 115, fig 7

Cells almost flat, black in colour Valves strongly silicified and very striking, diameter 46–135 μ, areolated, areolæ large more or less of the same size about 3 in 10 μ but very near the edge 5 in 10 μ. No central area or rosette Inner chamber openings clear Border of valve heavily striated

Distribution —In all the seas Also occurs in the Post-miocene of the Atlantic States and several other deposits (*cf* De Toni, 1891–94, p 1242).

17 *Coscinodiscus Granii* Gough

(Figs 33, 35 and 39)

Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 34, fig. 35, Lebour, *Plank Diat N Seas*, 1930, p 44, fig 20, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 436, fig 237, Venkataraman, *S I. Diat*, 1939, p 300, fig 16 and 17

Valves rounded, diameter 153–182 μ, areolated Middle areolæ larger than the rest forming a sort of rosette. Areolæ around rosette 4 in 10 μ. Chamber openings clear Covering membrane poroid Two asymmetrical pore canals at the margin. Cell in the girdle view wedge-shaped owing to the highest point of the valve being excentrically placed

Coscinodiscus Granii Gough var *aralensis* (Ostenf) Hustedt

(Fig. 37)

Differs from the type in having larger areolations

Distribution —Frequent in autumn and winter in the region of South North Sea The variety seen in the Aral Sea and Caspian Sea Type also recorded from brackish water in Madras

18 *Coscinodiscus Jonesianus* (Greville) Ostenfeld

(Figs 42, 45 and 48)

Hustedt, Rabenhorst's *Kryptogamen-Fl* , Bd VII, Teil 1, 1930 *b*, p 438, fig 239, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 116, fig 10

Eupodiscus Jonesianus Greville, *Descrip New and Rare Diat* 1862, Ser V, p 22, P. II, fig 3,

Coscinodiscus concinnus var. *Jonesiana* Rattray, *Revis Coscinodiscus*, 1888-89, p 532, De Toni, *Syll Alg* , Vol II, 1891–94, p 1257, Boyer, *Syn N. Am Diat* , 1926, p 55

Coscinodiscus radiatus var *Jonesiana* Van Heurck, *Traité des Diatomées*, 1899, p 531

Cells large, diameter 140–210 μ Areolæ in the centre forming a rosette, 4 in 10 μ; further outside about 9 in 10 μ Radial rows and spiral rows of areolæ clear and so also the chamber openings Interstitial meshes, possibly spinulæ, forming an irregular ring between the centre and the margin Hyaline radial ribs running to the centre from small spinulæ inside the margin Two large cone-shaped processes present near the margin about 120° apart

Coscinodiscus Jonesianus (Greville) Ostenfeld

var. *commutata* (Grun) Hustedt

(Figs. 43, 46 and 47)

Differs from the type in the somewhat larger areolation, rosette not very clearly differentiated Interstitial meshes present, but do not form regular ring.

Distribution —Purely marine, confined to the warmer seas; probably occurs in the Mediterranean Variety frequently in the region of South North Sea, East Sea and Caspian Sea

19 *Coscinodiscus concinnus* W Smith

(Figs 44, 50, 53, 54 and 56)

W Smith, *Syn Brit Diat*, Vol. II, 1856, p 85; Roper, *Notes on Brit. Mar Diat.*, 1858, Pl III, fig. 12; Pritchard, *Hist Inf*, 1861, p. 828, Pl V, fig 89, Rattray, *Revis Coscinodiscus*, 1888-89, p 531, De Toni, *Syll Alg.*, Vol II, 1891-94, p 1256; Gran, *Nord Plant*, *Bot Teil*, Bd. VIII, 1908, p XIX 33, fig 34; Boyer, *Syn N Am Diat*, 1926, p 55, Lebour, *Plank Diat N Seas*, 1930, p. 43, fig 19, Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd VIII, Teil 1, 1930 *b*, p. 441, figs 241 and 242

Coscinodiscus papuanus Castracane, *Diat Chall*, 1876, p. 154, Pl. III, fig. 3

Coscinodiscus nobilis Grunow, Allen and Cupp, *Plank Dias Java Seas*, 1935, p. 113, fig 13

Cells large, drum-shaped with slightly convex valves, thin walled and hyaline, diameter 210-420 μ Areolation slender with a well differentiated rosette of large meshes. Surrounding areolæ suddenly becoming smaller about 9-12 in 10 μ at the centre and 12 in 10 μ near the margin. Chamber openings indistinct Radial and secondary series regular Hyaline ribs running to the centre from distinct spinulæ near the margin. Interstitial meshes existing here and there Two small asymmetrical processes clearly seen at an angle of about 120° apart

Balsam preparations are colourless and hence the structure could not be made out in these Therefore, the material was mounted in styrax

Distribution—Marine, pelagic. Entire northern region of Europe, Java Sea, Vancouver, and Peruvian guano

20 *Coscinodiscus centralis* Ehrenberg

(Figs 49, 55, 58 and 59)

Rattray, *Revis. Coscinodiscus*, 1888-89, p. 555, De Toni, *Syll. Alg.*, Vol II, 1891-94, p 1272, Van Heurck, *Traité des Diatomées*, 1899, p 527; Gran, *Nord. Plank*, *Bot Teil*, Bd. VIII, 1908, p XIX 33, fig 33; Boyer, *Syn. N Am Diat*, 1926, p 56; Lebour, *Plank Diat. N Seas*, 1930, p. 39, figs 16 *a*, 17 *b*, 18 *b*, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 444, fig 243

Coscinodiscus centralis var. Castracane, *Diat. Chall.*, 1876, p. 155, P. II, fig. 3.

Cells disc-shaped, valves convex. Diameter 196 µ. Valve areolated with a clear rosette. In the middle part almost of same size 3 in 10 µ, but farther out 6 in 10 µ and at the margin 8 in 10 µ. Chamber openings clear Both radial and secondary spiral systems of areolæ present. Small spinulæ in a ring behind the margin of the valve, 1 to 2 in 10 µ. Two small asymmetrical processes present. Valve edge narrow and striated.

Distribution.—Whole of North Atlantic region. In the Gulf Stream region during winter. In the Oran deposits, Algeria.

21. *Coscinodiscus perforatus* var *Pavillardi* (Forti) Hustedt

(Figs 52, 57 and 61)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil, 1, 1930, *b* p 447, fig 247

Cells disc-shaped with slightly convex valves, diameter 145-170 µ Valves largely areolated with a central rosette Areolæ around the rosette 3–5 in 10 µ, towards the margin 3–4 in 10 µ Both radial and secondary systems of areolation present Interstitial meshes few and not present before all radii. Valve margin striated, striæ 6 in 10 µ Two asymmetrical processes present, but not very clear

Distribution —So far recorded only from the Mediterranean

22 *Coscinodiscus apiculatus* Ehrenberg

(Figs 51 and 60)

Rattray, *Revis Coscinodiscus*, 1888-89, p 570, De Toni, *Syll Alg*, Vol. II, 1891–94, p. 1282; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 449, fig 248

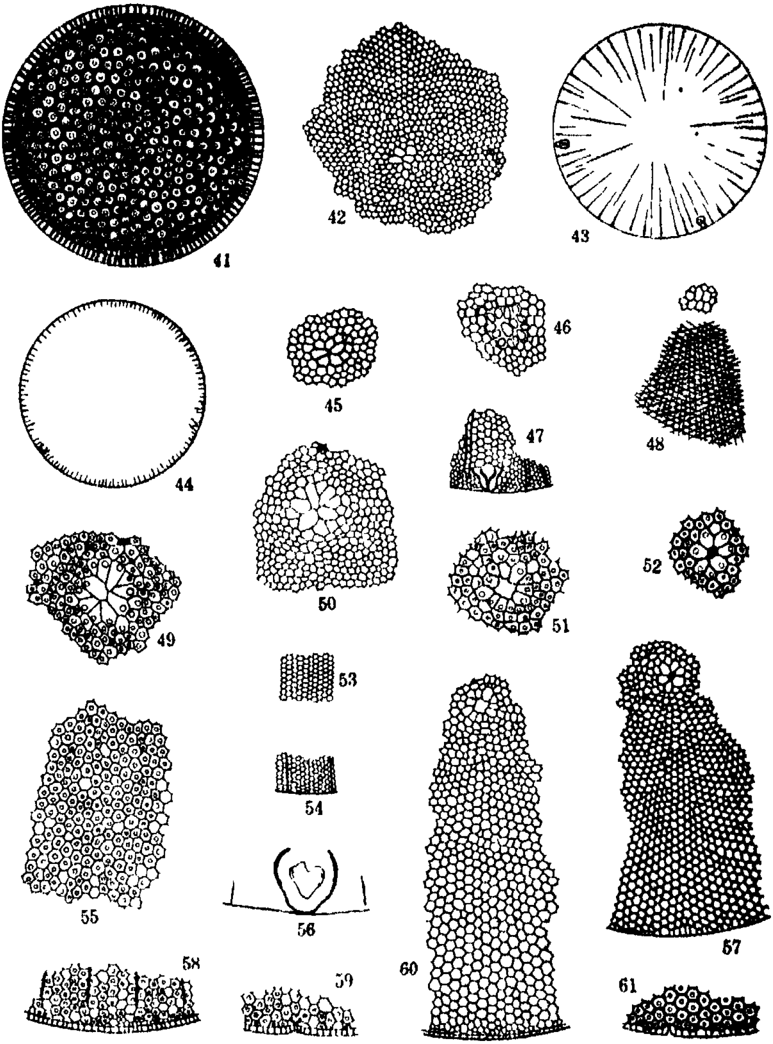
Cells disc-shaped, valves flat, diameter 217 µ, Central area small with a rosette. Areolation large, areolæ of almost same size 4 in 10 µ around the rosette and 3 in 10 µ near the margin Chamber openings clear Radial and secondary spiral series present Valve margin small, striated, striæ 6 in 10 µ. Two small indistinct asymmetrical processes present

Distribution —In all the seas and in several deposits (*cf* De Toni, 1891–94)

23 *Coscinodiscus Asteromphalus* Ehrenberg

(Figs. 62–65)

Rattray, *Revis. Coscinodiscus*, 1888-89, p. 549; De Toni, *Syll Alg*, Vol. II, 1891-94, p. 1268, Van Heurck, *Traité des Diatomées*, 1899, p 530, fig. 277; Boyer, *Syn. N. Am. Diat.*, 1926, p. 56; Hustedt, Rabenhorst's



Text-Figs 41–61 —Fig 41 *Coscinodiscus marginatus* Ehrenberg ×710 Fig 42 *C Jonesianus* (Greville) Ostenfeld ×710 Fig 43 *C Jonesianus* var *commutata* Hustedt ×220 Fig 44 *C concinnus* W Smith × 53 Fig 45 *C Jonesianus* (Greville) Ostenfeld, rosette, × 930 Figs 46–47 *C Jonesianus* var *commutata* Hustedt × 930 Fig 46, rosette; 47, Margin with process Fig 48 *C Jonesianus* (Greville) Ostenfeld Schematic representation of structure. × 710. Fig 49. *C centralis* Ehrenberg, rosette. × 930. Fig. 50. *C. concinnus* W. Smith, rosette. × 930 Fig. 51 *C apiculatus* Ehrenberg, rosette. × 710. Fig. 52 *C. perforatus* var *Pavillardii* (Forti) Hustedt, rosette ×710 Figs. 53–54 *C. concinnus* W. Smith. Fig 53, structure inside the margin, ×930, 54, margin, ×930 Fig 55. *C. centralis* Ehrenberg, structure of valve, away from the centre Fig. 56 *C concinnus* W. Smith, margin with process. ×930 Fig 57 *C perforatus* var *Pavillardii* (Forti) Hustedt. ×590. Figs 58–59 *C. centralis* Ehrenberg. Margin of the valve. ×930 Fig 60 *C apiculatus* Ehrenberg ×460. Fig. 61. *C. perforatus* var *Pavillardii* (Forti) Hustedt Margin ×710

Kryptogamen-Fl, Bd VII, Teil 1, 1930 *b*, p 452, fig 250; Allen and Cupp, *Plank. Diat Java Sea*, 1935, p. 119, fig 14

Cells disc-shaped, valves depressed in the middle, diameter 200–210 μ. Valve areolated, areolæ in radial rows. A large rosette in the centre with or without a clear area at its centre Areolæ polygonal, almost all of same size, 3 to 4 in 10 μ At the margin slightly smaller. Chamber openings clear. Outer membrane clearly punctate, punctæ 25 in 10 μ. Asymmetrical processes small. Margin striated, striæ 7 in 10 μ

In some specimens there appeared a disturbance of the rosette (Figs. 64–65)

Distribution.—In all seas, not a rare form Also in several Miocene deposits.

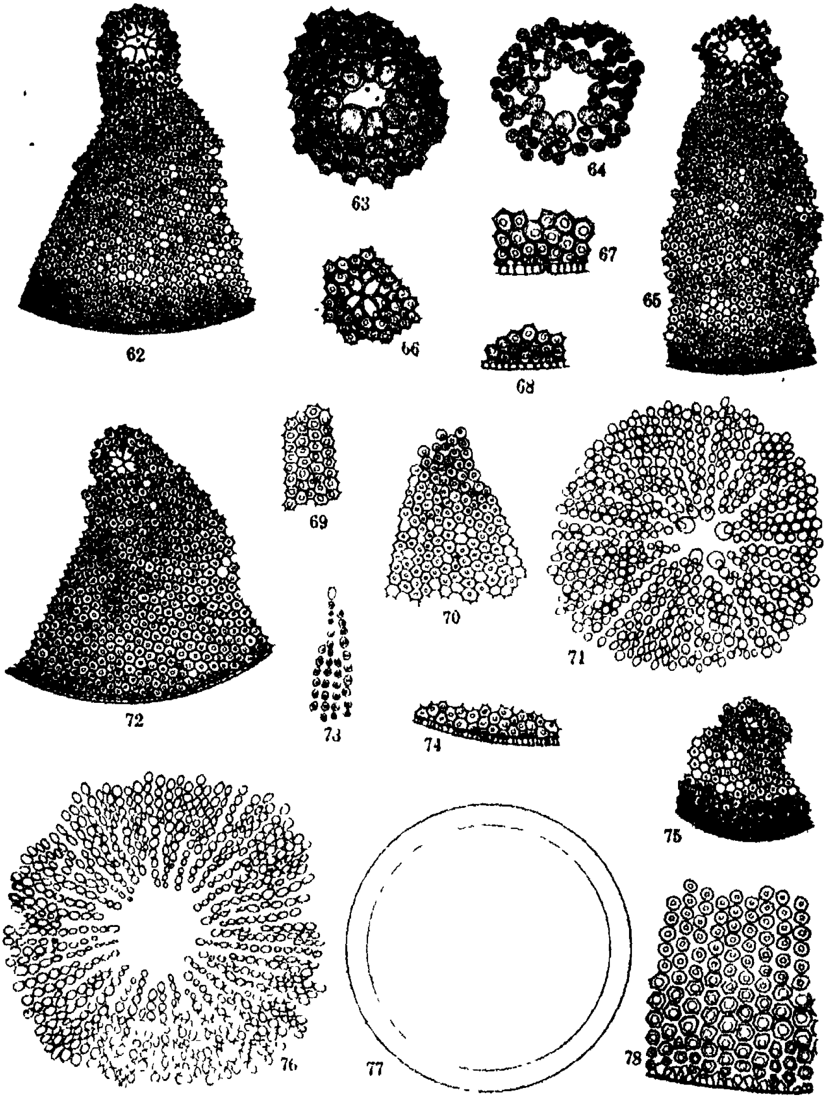
24 *Coscinodiscus oculus-iridis* Ehrenberg

(Figs 66–68 and 72)

Rattray, *Revis Coscinodiscus*, 1888-89, p 559; De Toni, *Syll. Alg.* Vol II, 1891-94, p 1275; Boyer, *Syn. N Am Diat*, 1926, p 57, Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd VII, Teil 1, 1930 *b*, p 454, fig. 252; Allen and Cupp, *Plank. Diat. Java Sea*, 1935, p. 119, fig. 15.

Cells disc-shaped, large, dark coloured and striking, diameter 160–170 μ. Areolation large with a central rosette which sometimes shows a small area. Areolæ increase in size slightly towards the margin 3 in 10 μ around the rosette, 2½ in 10 μ still farther out and at the margin smaller, being 4–5 in 10 μ. Inner chamber openings clear. Radial and secondary spiral series well expressed. Margin small, radially striated, striæ 6 in 10 μ. Two assymmetrical pore canals seen on careful examination.

Distribution.—In the marine plankton of all seas Also recorded in fossils.



62–78 Figs 62–65 *C asteromphalus* Ehrenberg Fig 62, ×456; 63, 64, 65, ×930, 64 and 65, note slight disturbance of areolæ at the centre Figs. 66–68 *C. oculus-iridis* Ehrenberg × 930 Fig 66, rosette, 67 and 68, margin. Fig. 69. *C. gigas* Ehrenberg var. *prætexta* (Janisch) Hustedt Structure away from the centre × 710 Figs. 70–71 *C Janischii* A. Schmidt, central area ×710 Fig 72. *C oculus-iridis* Ehrenberg ×460 Fig. 73. *C. gigas* Ehrenberg var. *prætexta* (Janisch) Hustedt ×710 Few areolæ near the centre. Fig. 74. *C. Janischii* A Schmidt, margin × 710. Fig 75 *C oculus-iridis* Ehrenberg var *borealis* (Bailey) Cleve. × 710. Figs 76–78. *C gigas* Ehrenberg var *prætexta* (Janisch) Hustedt Fig. 76, central area ×710; 77, cell under low power, ×53; and 78, margin of the valve, ×710

Coscinodiscus oculus-iridis Ehrenberg
var *borealis* (Bailey) Cleve

(Fig 75)

Rattray, *Revis. Coscinodiscus*, 1888-89, p 558; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 456, fig 253

Coscinodiscus borealis Bailey, *Notice Micr. Forms*, 1856, p 3; De Toni, *Syll Alg*, Vol II, 1891–94, p. 1274

Differs from the type in having robust valves, larger areolæ, 3 in 10 μ around the rosette and 2 to 2½ in 10 μ near the margin. Diameter of valve 85 μ

Distribution—Type in the marine plankton of all the seas; also recorded in fossils. In the northern seas, in the southern regions rare Kamtschatka Sea, Behring Sea. Hong Kong. Also from some fossil deposits.

25 *Coscinodiscus gigas* Ehrenberg
var. *prætexta* (Janish) Hustedt

(Figs 69, 73 and 76–78)

Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930 *b*, p. 457, fig. 255 and 256 *b*; Allen and Cupp, *Plank Diat. Java Sea*, 1935, p. 120, figs. 16, 16 *a*, 16 *b*

Cells disc-shaped, valves flat. Diameter 476–532 μ. Central area large. Areolæ very near the margin about 5 in 10 μ; then become large 2 in 10 μ, forming a dark broad band. Towards the centre more delicate and hyaline, about 3 in 10 μ and rounded Chamber openings distinct only near the periphery of the valve. Outer membrane in the marginal region punctate. Areolæ arranged in radial and spiral systems. Two small asymmetrical processes at an angle of 120° present on the valve.

Distribution.—Pelagic, widely distributed in the southern seas, Mediterranean Sea. Type found in fossils also.

26. *Coscinodiscus Janischii* A. Schmidt

(Figs 70, 71 and 74)

Rattray, *Revis. Coscinodiscus*, 1888-89, p. 543; De Toni, *Syll. Alg.*, Vol. II, 1891–94, p. 1264; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930 *b*, p 459, fig 257, Allen and Cupp, *Plank. Diat. Java Sea*, 1935, p. 120, fig 17.

Cells disc-shaped, with almost flat valves, which are slightly concave in the centre, diameter 210μ. Central area small. Areolæ on a small marginal zone well marked and in the remaining slender, almost of same size 4 in 10μ; but at the margin 2½ in 10μ. Chamber openings clear Valve margin small, striated Two pore canals placed asymmetrically, not very clear.

Distribution—Only in warm regions In Europe only in the Mediterranean

IX Genus *Planktoniella* Schutt

27 *Planktoniella Sol* (Wallich) Schütt

(Figs. 79, 80 and 83)

Rattray, *Revis. Coscinodiscus*, 1888-89, p. 466, Van Heurck, *Traité des Diatomées*, 1899, p. 534, fig 280, Karsten, *Valdivian Expedn.*, 1907, p. 514, Pl. XXXIX, figs. 1–11; Gran, *Nord Plank, Bot, Teil*, Bd. VIII, 1908, p XIX 44, fig 48, Lebour, *Plank Diat N Seas*, 1930, p 50, Pl I, fig 5; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd VII, Teil 1, 1930 *b*, p. 465, fig. 259; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 121, fig. 19

Coscinodiscus Sol Wallich, *Siliceous Organisms*, 1860, p. 38, figs. 1 and 2; De Toni, *Syll Alg.*, Vol II, 1891-94, p 1212

Planktoniella Woltereckii Schimper, Karsten, *Valdivian Expedn*, 1907, p. 157, Taf. XXVII, fig. 3.

Cells disc-shaped with flat valves, diameter 67-71μ Valve surface areolated, areolæ exactly arranged as those of *Coscinodiscus excentricus*. Areolæ 12 in 10μ Wing-like expansion all round the cell, weakly silicified and with radial rays

Fig 80 shows a specimen of this genus with valves identical with that of the type described here but differing in the nature of the wing. Karsten (1907, Pl XXXIX, fig 2) includes forms such as these under this species and says that they are developmental stages. Only one specimen was seen by the writer.

Distribution.—Widely distributed in the plankton of the warmer seas. In Europe only in the Mediterranean region.

Family Actinodisceæ

Sub-family Actinoptychineæ

X Genus *Actinoptychus* Ehrenberg

28 *Actinoptychus undulatus* (Bailey) Ralfs

(Fig. 82)

Pritchard's *Hist. Infusoria*, 1861, p 839, Pl V, fig 88; De Toni, *Syll. Alg.*, Vol. II, 1891-94, p 1372; Van Heurck, *Traité des Diatomées*, 1899, p. 496, Pl. XXII, fig. 648 and text-fig 232, Gran, *Nord Plank.*, *Bot Teil*, Bd. VIII, 1908, p XIX 42, fig 46; Boyer, *Syn N. Am. Diat*, 1926, p. 64; Lebour, *Plank Diat N Seas*, 1930, p 51, fig 27; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 475, fig 264, Allen and Cupp, *Plank Diat. Java Sea*, 1935, p 121, fig 20

Actinocyclus undulatus Bailey, *Sketch of infusoria*, etc, 1842, Pl II, fig. 11; Kützing, *Sp Alg*, 1849, p 127, W Smith, *Syn Brit Diat*, Vol 1, 1853, p. 25, Pl. V, fig 43

Cells disc-shaped with undulating valves, diameter 34-53 μ Valve with six sectors of the same size Central area hexogonal. The raised sectors possess a short blunt process in the middle near the margin; the surface strongly areolated and punctate; areolæ 6 in 10 μ, more or less regular; punctæ in radial and in oblique rows, 12 in 10 μ Depressed sectors without process; areolæ not so prominent; instead a weakly differentiated net-work of lines Punctate.

Distribution.—In the coastal region of all seas In the Mediterranean slightly more frequent than N Europe. Java seas Atlantic and Pacific coasts of America Miocene deposits of the eastern states.

Sub-family Asterolamprineæ

XI. Genus *Asteromphalus* Ehrenberg

29. *Asteromphalus flabellatus* (Brébisson) Greville

(Figs. 81 and 85)

Greville, *Diat. Cal. Guano*, 1859 *b*, p. 160, Pl. VII, fig. 4, 5; De Toni, *Syll. Alg.*, Vol. II, 1891-94, p. 1414, Van Heurck, *Traité des Diatomées*, 1899, p. 504; Boyer, *Syn N. Am. Diat.*, 1926, p. 74; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd VII, Teil 1, 1930 *b*, p. 498, fig 279; Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 123, fig 22

Asterolampra flabellata Greville, *Mon. Genus Asterolampra*, etc., 1860, p. 116.

Cells slightly convex. Valves ovate, long axis 38–61 μ, short axis 32-54 μ. Middle field excentric. Sector lines of middle are unbranched. Hyaline rays 7 to 8, 1 5 μ wide; one slightly narrower, reaching margin of the valve. Rays slightly curved. Border segments areolated in three lines system, areolæ about 15 in 10 μ.

Distribution.—In the Mediterranean, Campeche Bay and Java seas; Peruvian guano.

30. *Asteromphalus Cleveanus* Grunow

(Figs. 84 and 88)

Cleve, *Exam. Diat Sea of Java*, 1873 *a*, p. 5, Pl. 1, fig 1; Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 123, fig 22

Cells very similar to those of *A flabellatus* Valves ovate, long axis 68–79 μ, short axis 56-58 μ. Sector lines branched, hyaline rays 11 to 12 slightly curved. Segments 12 to 13, areolated as in *A flabellatus*; areolæ 12 in

Distribution.—Java Sea.

31. *Asteromphalus Wyvillei* Castracane

(Fig. 87, Pl. II, fig. 4)

Castracane, *Diat Chall*, 1876, p 134, Pl V, fig. 6, Karsten, *Valdivian Expedn*, 1907, p. 370, Pl. XXXVIII, figs. 4 and 4*a*

Cells round, diameter 70 μ. Central area smaller compared to former species. Hyaline radii 15, more or less straight, 2 5 μ broad; one considerably narrower. Sector lines branched. Segments wedge-shaped, areolated in three lines system, areolæ 12 in 10 μ. Chromatophores numerous small discs.

The diatom is a very beautiful object under the microscope, especially in the living condition.

Distribution.—Indian Ocean.

Family Eupodisceæ

Sub-family Pyrgodiscineæ

XII. Genus *Gossleriella* Schutt

32. *Gossleriella tropica* Schutt

(Fig 86)

Schutt, *Pflanzenleb. d Hochsee*, 1893, p. 20 Van Heurck, *Traité des Diatomées*, 1899, p 513, fig. 265, Karsten, *Valdivian Expedn*, 1907, p 368, Taf XL, figs 14–17, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 500, fig 280.

Cells with flat valves, diameter 182–196 μ. Valve surface appearing more or less structureless. Valve border with a ring of spines 28–57 μ long of which several are striking owing to thicker silicification; the stronger ones bifid and swollen at the base and between two such several weaker spines are situated, Chromatophores numerous small discs

Distribution.—Typical plankton form in the Mediterranean Sea. Indian Ocean.

Sub-family Aulacodiscineæ

XIII. Genus *Aulacodiscus* Ehrenberg

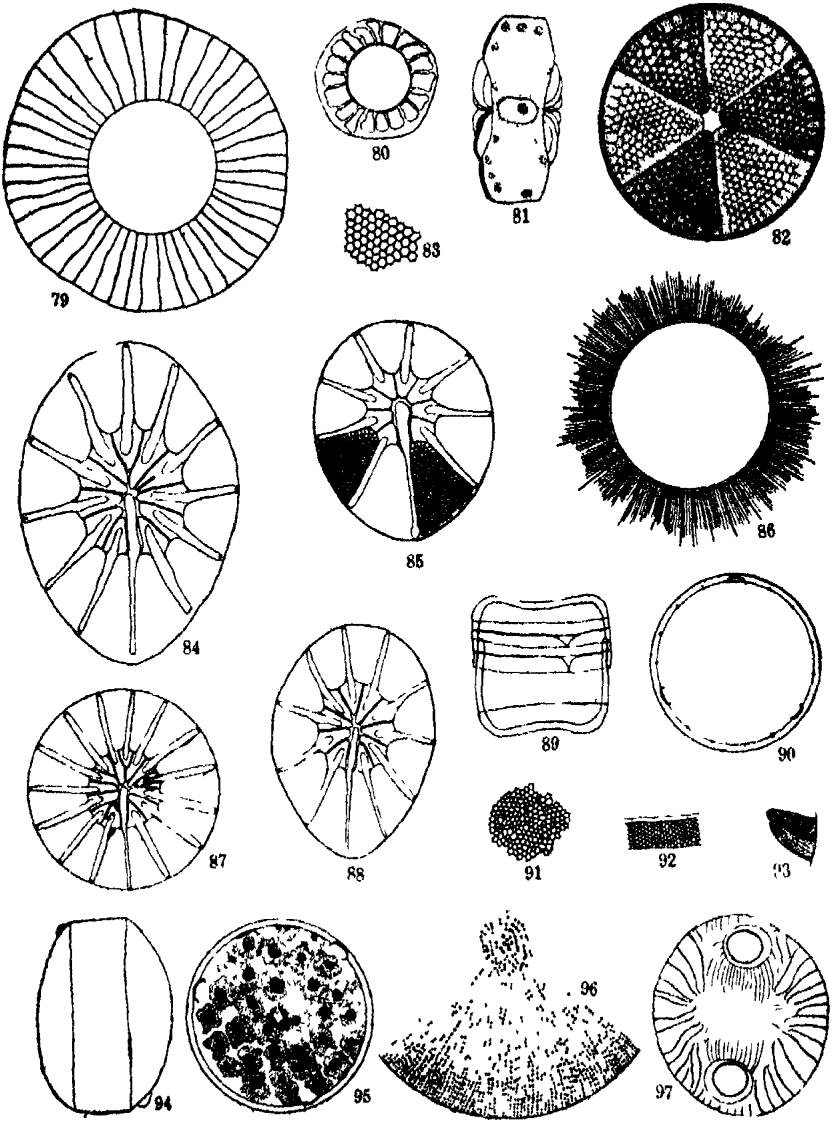
33. *Aulacodiscus orbiculatus* sp nov

(Figs. 90, 91, 94 and 95)

Cells disc-shaped, 74–114 μ in diameter. Valves without radial elevations. Ground membrane of the valve closely areolated, areolæ 6 in 10 μ. Areolæ at the centre irregularly arranged, towards the border somewhat radial. In cleared preparations the central portion (a circular area of about ⅓ the diameter of the valve) whitish, the remaining portion appearing brownish in colour. Three distinct processes on the valve, knob-like, placed equally apart. A number of pore canals a little within the border Chromatophore several lobed discs with a central pyrenoid.

This form in the living condition, shows an apparent resemblance to *A. argus* Ehrenberg but differs in the details of the structure. In *A. argus*, over the ground membrane of the valve there is a net-like structure with wide meshes which is not present in the specimens described here. Again, the processes in *A. argus* are teat-shaped whereas in the present form they are rounded and knob-like.

Distribution.—Plankton of the Madras coast.



TEXT-FIGS. 79–97.—Fig. 79 *Planktoniella Sol* (Wallich) Schütt. × 328 Fig. 80. *Planktoniella Sol* (?) × 460. Fig. 81. *Asteromphalus flabellatus* (Brébisson) Greville. × 710

Girdle view. Fig 82 *Actinoptychus undulatus* (Bailey) Ralfs × 710 Fig 83 *Planktoniella Sol* (Wallich) Schütt Structure of the valve, × 930 Fig 84 *Asteromphalus Cleveanus* Grunow ×460 Fig 85 *Asteromphalus flabellatus* (Brébisson) Greville Structure shown only in two of the segments × 930 Fig 86 *Gossleriella tropica* Schütt ×150 Fig 87 *Asteromphalus Wyvillei* Castracane × 460 Fig 88 *A Cleveanus* Grunow × 460 Fig 89. *Actinocyclus Ehrenbergii* Ralfs Cell in girdle view ×710 Figs 90-91 *Aulacodiscus orbiculatus* sp. nov. Fig 90, valve, ×325 Fig 91, structure on valve, ×930 Fig 92 *Actinocyclus Ehrenbergii* Ralfs. Structure of the girdle ×930 Fig 93 *Auliscus sculptus* (W Smith) Ralfs Structure of ribs ×710 Figs 94, 95 *Aulacodiscus orbiculatus* sp nov Fig 94, Girdle view of cell, 95, valve view, ×328 Fig 96 *Actinocyclus Ehrenbergii* Ralfs Structure of a portion of the valve. × 930. Fig 97 *Auliscus sculptus* (W. Smith) Ralfs × 710.

Sub-family Eupodisceneæ

XIV Genus *Auliscus* Ehrenberg

34 *Auliscus sculptus* (W Smith) Ralfs

(Figs 93 and 97, Pl II, fig. 6)

Pritchard, *Hist Infusoria*, 1861, p. 845, Pl VI, fig 3, Greville, *Mon Genus Auliscus*, 1863 *b*, p 43, Pl. II, figs 1-3, Rabenhorst, *Fl. Eu Alg*, 1864, pt. 1, p. 320, Rattray, *Revis Auliscus*, 1888, p. 23, De Toni, *Syll. Alg.*, Vol. II, 1891-94, p. 1047; Van Heurck, *Traité des Diatomées*, 1899, p. 482, fig 215, Pl. XXI, fig 646; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p. 516, fig 290.

Eupodiscus sculptus W Smith, *Syn Brit Diat*, Vol I, 1853, p. 25, Pl. IV, fig. 42.

Cells disc-shaped with broadly elliptic valvar plane, long axis 46 µ, short axis 41·5 µ. Two hyaline eyes of 11 5 µ in diameter opposite each other. Valves sculptured with strong radial ribs which become faint towards the centre Valves radially striated, striæ 24 in 10 µ. Central area hyaline, more or less oblong with round corners

Distribution.—In all the European seas particularly in the region of North Sea; West Indies.

XV. Genus *Actinocyclus* Ehrenberg

35 *Actinocyclus Ehrenbergii* Ralfs.

(Figs. 89, 92 and 96)

Pritchard, *Hist Infusoria*, 1861, p 834; De Toni, *Syll Alg*, Vol. II, 1891-94, p. 1177; Van Heurck, *Traité des Diatomées*, 1899, p 523, Pl XXIII, fig. 659, Gran, *Nord Plank*, *Bot Teil*, Bd. VIII, p. XIX, 40, 1908; Boyer, *Syn. N Am Diat.*, 1926, p 84; Lebour, *Plank. Diat. N. Seas*, 1930, p. 53, Pl. II, fig. 1; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd, VII, Teil 1, 1930 *b*, p. 525, 298.

Eupodiscus crassus W. Smith, *Syn Brit Diat*, Vol I, 1853, p 24, Pl IV, fig. 41.

Cells strongly silicified, disc-shaped, slightly convex, 33–61 μ in diameter. Dark-brown in colour in mounts, with shades of green, blue and purple. Central area small, with scattered areolæ Areolæ in series, divided into structure-sectors by hyaline radial rays running from the centre to the margin to different lengths. Areolæ 9 in 10 μ; under low magnification round, but under higher powers polygonal In the sub-marginal zone about 15 in 10 μ. A hyaline eye present. Valve margin finely striated, striæ scarcely visible.

Distribution.—In all the European seas, near the coast, Atlantic and Pacific coasts of America Peruvian guano

Sub-Order SOLENOIDEAE

Family Solenieæ

Sub-family Lauderineæ

XVI Genus *Corethron* Castracane

36 *Corethron hystrix* Hensen

(Figs 99, 101 and 103)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 547, fig 311, Boyer, *Syn N Am Diat*, 1926, p 114

Corethron criophilum Castracane, *Diat Chall*, p 85, Pl XXI, figs. 12, 14, 15; De Toni, *Syll Alg*, Vol II, 1891–94, p. 1006; Gran, *Nord Plank.*, *Bot Teil*, 1908, Bd VIII, p XIX 57, fig. 70, Lebour, *Plank. Diat. Seas*, 1930, p 80, fig 54; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 123, fig. 24.

Cells with cylindrical mantel face and semicircularly bulged valves, 36–58 μ in diameter; weakly silicified. The valve margin with a crown of long thin spines directed outwards, those of the two valves directed in the same direction. Chromatophores numerous, small and disc-shaped, distributed at the periphery.

Distribution.—Pelagic in the region of the North Atlantic extending very much north, scattered. Java Seas.

37. *Corethron inerme* Karsten

Karsten, *Valdivian Expedn.*, 1907, p 104, Taf. XIII, fig 14

(Fig 98)

Cells with cylindrical mantel face and semicircularly bulged valves of about 41 μ diameter Weakly silicified The valve margin with a crown of long thin spines directed outwards, those of the two valves directed in opposite directions Chromatophores many, small, disc-shaped, some lobed, placed peripherally

Distribution—Pelagic in the warmer seas In Europe, scattered in the Mediterranean Sea

XVII Genus *Lauderia* Cleve

38. *Lauderia annulata* Cleve

(Figs 100 and 102)

Cleve, *Examn Diat Sea of Java*, 1873 a, p 8, Castracane, *Diat Chall. Expedn.*, 1876, p 89, Pl. VIII, fig 7, De Toni, *Syll Alg*, Vol II, 1891–94, p 771; Boyer, *Syn. N Am Diat*, 1927, p 561, Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 124, fig 25.

Lauderia borealis Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p. XIX 23, fig 22; Van Heurck, *Traité des Diatomées*, 1899, p 418, fig. 136; Lebour, *Plank Diat N Seas*, 1930, p 66, fig 38, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 549, fig 313

Cells cylindrical, valves slightly convex with a depression in the middle' 57–85 μ in diameter, forming a straight chain, the raised portion of the valve touching the adjacent cell Valves with numerous short spines of varying length Intercalary bands many, collar-shaped Surface of cell delicately punctate, punctæ 12 in 10 μ

Distribution—Pelagic in the coastal region of Europe, from the Mediterranean to North Norway; Java.

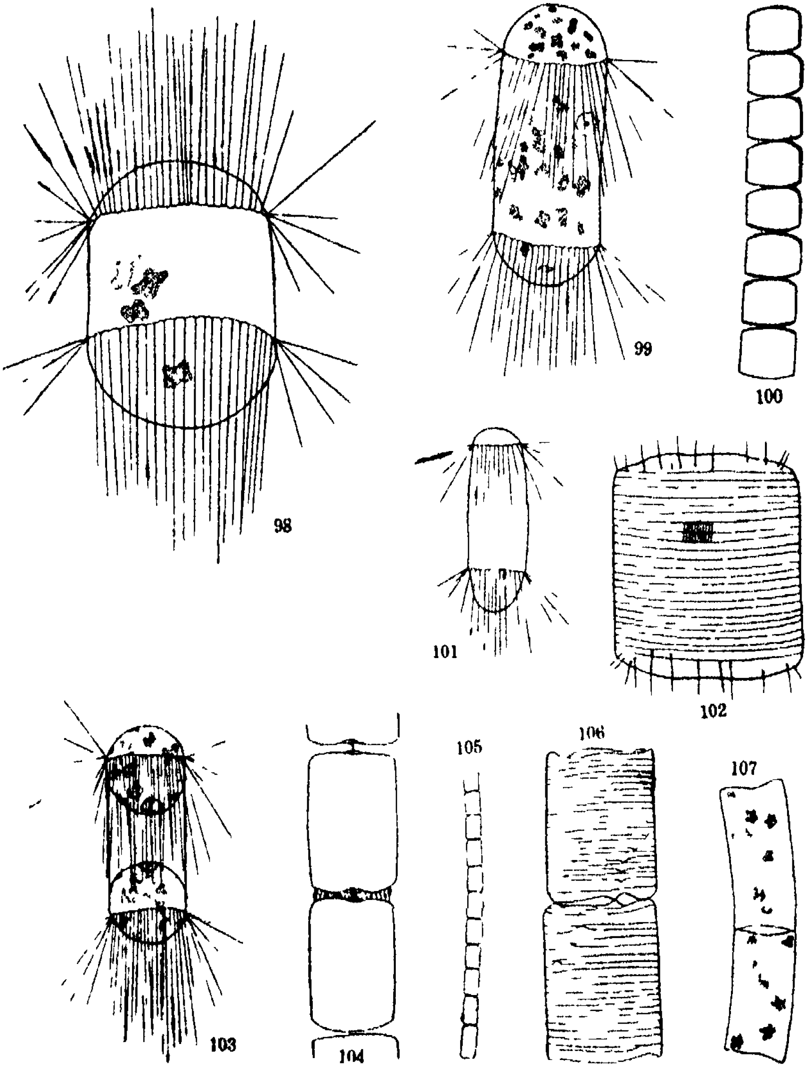
XVIII Genus *Schroederella* Pavillard

39. *Schroederella delicatula* (Peragallo) Pavillard

(Fig 104)

Hustedt, Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 1, 1930 *b*, p. 551, fig. 314; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 124

Detonula Schroederi Gran, Karsten, *Valdivian Expedn*, 1907, p 375, Taf. XLI, fig. 21; Gran, *Nord. Plank.*, *Bot. Teil*, Bd. VIII, 1908, p. 22, fig. 21,



Text-Figs 98-107 —Fig. 98 *Corethron inerme* Karsten. ×710. Fig. 99 *C hystrix* Hensen. × 460. Fig 100 *Lauderia annulata* Cleve. × 150. Fig. 101 *Corethron hystrix* Hensen. × 930. Fig. 102. *Lauderia annulata* Cleve. Details of structure shown only on a small portion. × 460. Fig. 103. *Corethron hystrix* Hensen. Daughter cells. × 328. Fig. 104.

delicatula **(Peragallo) Pavillard. × 710. Figs. 105–107 *Guinardia flaccida* (Castracane) Peragallo Fig 106, two cells, ×328, 107, two cells with chromatophores, ×328 Fig. 105, a chain, ×73**

Cells cylindrical with more or less slightly convex valves, valves depressed in the middle; diameter 14–39 μ. Cells bound in chains. Valves with a crown of spines. In the centre of each valve a spine-like pore canal present.

Finer structure on the valve could not be made out in the formalin material.

Distribution.—Preponderatingly confined to the warmer seas Not rare in the Mediterranean Atlantic coast of France and Spain; Java and Indian ocean

XIX Genus *Leptocylindrus* Cleve

40 *Leptocylindrus danicus* Cleve

(Figs 109 and 110)

Cleve, *Plank Cillico Diat*, 1894-95, p 15, P II, figs 4, 5; De Toni, *Syll. Alg.*, Vol. II, 1891-94, p 822; Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p. XIX 24, fig. 24; Boyer, *Syn. N Am Diat*, 1927, p. 559; Lebour, *Plank. Diat. N. Seas*, 1930, p 77, fig 52; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, 558, fig 319

Cells cylindrical, 3-17 μ in diameter and 9–89 μ in length, forming long chains No structure visible on the valve. Chromatophores, numerous and disc-shaped

Distribution—Neritic in the European coast, particularly frequently in North Europe and Mediterranean

41 *Leptocylindrus minimus* Gran

(Fig. 108)

Lebour, *Plank. Diat N. Seas*, 1930, p 78, fig. 52 *c*; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 560, fig. 321.

Cells very small, 2 5 μ in diameter and 26–29 μ in length, forming chains. Chromatophores two, large and disc-shaped.

Distribution—Davis Strait, Kiel, Flemish coast and English Channel.

Sub-family Rhizosoleninæ

XX Genus *Guinardia* Peragallo

42 *Guinardia flaccida* (Castracane) Peragallo

(Fig. 105–107)

De Toni, *Syll. Alg.*, Vol. II, 1891–94, p 823; Van Heurck, *Traité des. Diatomées*, 1899, p. 417, fig. 135; Boyer, *Syn N Am. Diat.*, 1927, p 559; Lebour, *Plank Diat. N. Seas*, 1930, p 79, fig 53; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930 *b*, p 562, fig 322; Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 125, fig 28

Rhizosolenia flaccida Castracane, *Diat Chall Expedn*, 1876, p. 74, Pl. XXIX, fig 4

Cells cylindrical, diameter 32–64 μ, forming long chains, at times, about 546 μ long; weakly silicified. Valve slightly concave. Intercalary bands numerous, collar-like No visible sculpture on the valves. Cells breaking down in the preparations Chromatophores many lobed discs each disc showing a pyrenoid.

Distribution.—Neritic. North Sea, Baltic Sea, Danish Sea, Skaggerak; North Atlantic, European and American; English Channel, Mediterranean, Java Seas.

XXI Genus *Rhizosolenia* Ehrenberg

A. SIMPLICES

43 *Rhizosolenia cylindrus* Cleve

(Figs. 111 and 112)

Karsten, *Valdivian Expedn.*, 1907, p. 376, Taf. XLII, fig 6, Gran, *Nord. Plank*, *Bot. Teil*, Bd VII, 1908, p. 49, fig. 56; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd, VII, Teil 1, 1930 *b*, p. 572, fig. 325; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 127, fig 30.

Cells cylindrical, diameter 23 μ, with conical valves. Process large, somewhat bent. Cell-wall hyaline, structure difficult to make out. *Richella intracellularis*, a blue green, often found inside the cell.

Distribution—Inhabits warmer regions, Indian Ocean, Java Seas, California, Atlantic Ocean.

B EURHIZOSOLENIAE

ANNULATAE

(*a*) *Lauderioideæ*

44. *Rhizosolenia Stolterfothii* H Peragallo

(Figs 113, 115 and 117)

De Toni, *Syll Alg*, Vol II, 1891-94, p 824, Van Heurck, *Traité des Diatomées*, 1899, p. 416, Karsten, *Valdivian Expedn.*, 1907, p. 163, Taf XXIX, fig. 9; p 378, Taf. XLI, fig. 3; Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 49, fig 55; Boyer, *Syn N Am Diat*, 1927, p 558; Lebour, *Plank. Diat N Seas*, 1930, p 93, fig 66, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 578, fig 329; Allen and Cupp, *Plank Diat. Java Sea*, 1935, p. 127, fig 29

Eucampia striata Stolterfoth, *New Sp of the Genus Eucampia*, 1879, p 835.

Cells cylindrical, 18–35 µ in diameter and up to 155 µ in length with uniformly bent pervalvar axis, forming compact, spirally coiled chains. Valve with small spine which fits into a depression in the adjoining cell. Intercalary bands ring shaped, numerous, without any visible structure. Cells weakly silicified. Chromatophores numerous, small, disc-shaped.

Distribution.—In the coast of Europe from the Mediterranean to North Norway; North Atlantic, both European and American; California; and Indian Ocean

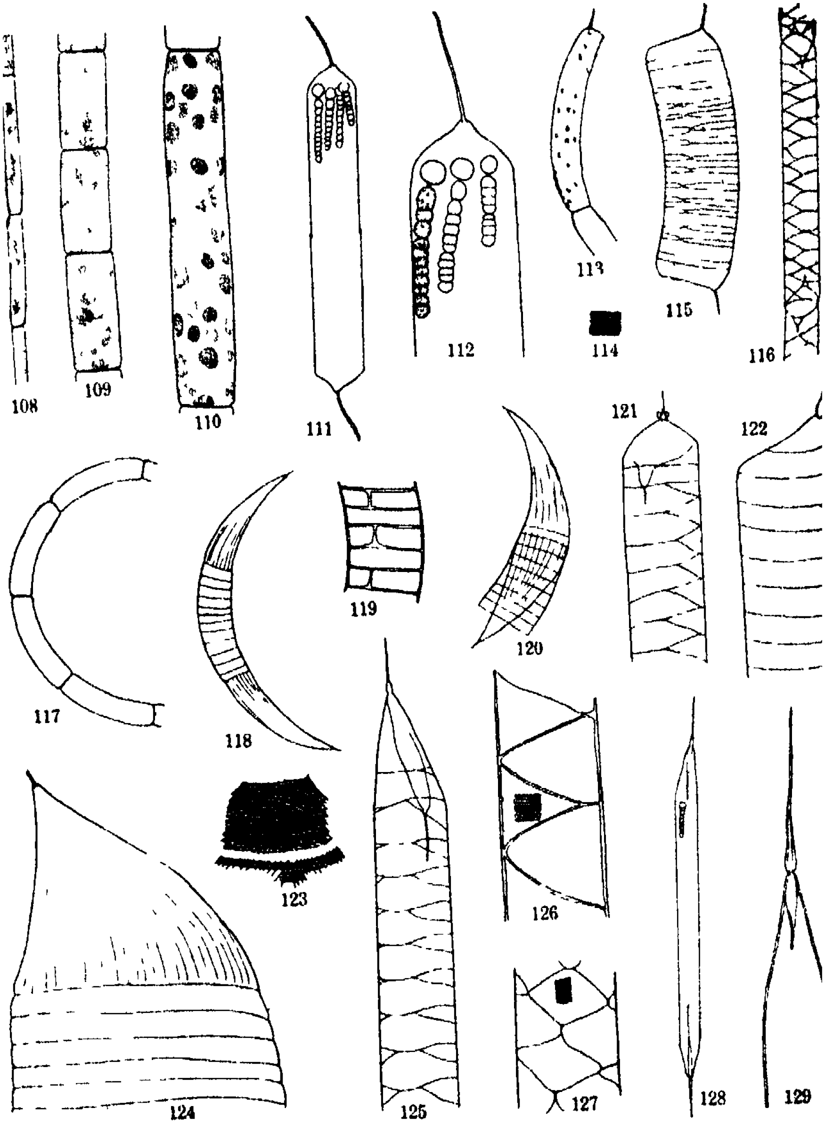
(*b*) *Robustæ*

45 *Rhizosolenia robusta* Norman

(Figs 118–120 and 124)

Pritchard, *Hist. Infusoria*, 1861, p 866, Pl VIII, fig 42; Castracane, *Diat. Chall*, 1876, p. 73, Pl. XXIV, fig 5, De Toni, *Syll Alg*, Vol. II, 1891–94, p. 824; Karsten, *Valdivian Expedn*, 1907, p 163, Taf XXIX, fig 10; Gran, *Nord Plank.*, *Bot. Teil*, Bd VIII, 1908, p XIX 50, fig 57, Van Heurck, *Traité des Diatomées*, 1899, p. 414, Pl XXXIII, fig. 883, Boyer, *Syn. N Am. Diat*, 1926, p 99, Lebour, *Plank Diat N Seas*, 1930, p. 94, fig. 68; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd VII, Teil 1, 1930 *b*, p 578, fig. 31; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 127, fig 31.

Cells cylindrical, in the middle part, with conical curved valves 53–266 µ in diameter. Intercalary bands robust, many, collar-shaped. A small spine set in the hollow apical process of the valve. Cell-wall thin,



Text-Figs. 108–129.—Fig. 108 *Leptocylindrus minimus* Gran. ×930 Figs 109–110. L

Figs. 111–112. *Rhizosolenia cylindrus* Cleve. Note *Richelia intracellularis*

Fig. 111, × 328; 112, × 710. Fig 113 *R. Stolterfothii* Peragallo × 985. Fig. 114. *R. styliformis* Brightwell. × 930. Structure of intercalary band Fig 115 *R Stolterfothii* Peragallo. ×328 Fig. 116. *R. imbricata* Brightwell ×150 Fig 117. *R. Stolterfothii* Peragallo. × 80 Figs. 118–120 *R. robusta* Norman Fig. 118, × 80, 119, × 220, 120, daughter cell with one parental valve. × 80. Figs. 121–123 *R. imbricata* Brightwell Figs 121 and 122, × 325, 123, structure, × 930 Fig. 124 *R robusta* Norman. × 220 Fig. 125. *R styliformis* Brightwell. × 220. Figs 126–129. *R. styliformis* var *longispina* Hustedt Figs 126, 127, × 710, 128, cell with *Richelia*, , 129, ×460.

easily breaking down; very finely punctate, punctæ in three line system crossing one another.

Distribution.—In warmer seas more frequent In Europe common from the Mediterranean to the English Channel; north Pacific coast of America.

GENUINAE

(*a*) *Imbricatæ*

46 *Rhizosolenia imbricata* Brightwell

(Figs 116, 121-123)

Brightwell, *Remarks on the Genus Rhizosolenia*, 1858 *a*, p 95, Pl V, fig. 6; Pritchard, *Hist Infusoria*, 1861, p 865, Castrarane, *Diat. Chall*, 1876, p. 73, Pl. XXIV, fig 1 and 1 bis; Van Heurck, *Traité des Diatomées*, 1899, p 415, Pl XXXIII, fig 885, De Toni, *Syll Alg*, Vol II, 1891-94, p 828; Karsten, *Valdivian Expedn*, 1907, p 98, Taf XI, fig 3, Gran, *Nord. Plank*, *Bot Teil*, Bd VII, 1908, p XIX, 52, fig 63; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, 580, fig 331, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 129, fig 35

Cells cylindrical, 38–44 μ in diameter Intercalary bands numerous in two series. Apical process short and straight, base slightly enlarged with lateral wings at the base. Cell-wall strong, clearly sculptured Intercalary bands coarsely punctate-striated, striæ running from central line in a fan-like manner to sides, 15 in 10 μ; punctæ 30 in 10 μ.

Distribution.—Maximum development in the warmer seas The Mediterranean. Java Seas

(*b*) *Styliformis*

47. *Rhizosolenia styliformis* Brightwell

(Figs 114 and 125)

Brightwell, *Remarks on the Genus Rhizosolenia*, 1858 *a*, *p* 95, Pl. V, fig 5 *d*; De Toni, *Syll. Alg*, Vol. II, 1891–94, p. 826, Van Heurck, *Traité des*

Diatomées, 1899, p. 415, Pl. XVII, fig. 601; Karsten, *Valdivian Expedn.*, 1907, p. 96, Taf. X, fig. 5; Gran, *Nord Plank., Bot. Teil*, Bd. VIII, 1908, p. 54, fig. 65; Boyer, *Syn. N. Am. Diat*, 1926, p. 99; Lebour, *Plank Diat. N. Seas*, 1930, p. 98, fig. 71; Hustedt, Rabenhorst's *Krypsogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 584, fig 333; Allen and Cupp, *Plank. Diat. Java Sea*, 1935, p. 130, fig. 39.

Cells cylindrical, diameter 23–98 μ and up to 392 μ length. Intercalary bands scale like in two rows, scales alternating with each other; punctate, punctæ about 20 rows in 10 μ. Process more or less long, hollow. The wings not clearly visible. Often, the blue-green alga *Richelia intracellularis* found inside.

Rhizosolenia styliformis Brightwell

var. *longispina* Hustedt

(Figs. 126–129)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p. 586, fig 334; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 130, fig. 39.

Differs from the type in its longer apical process ending in long spines. The base of the process thinned Punctæ 25 rows in 10 μ. Diameter of cell 54 μ.

Rhizosolenia styliformis Brightwell

var. *latissima* Brightwell

(Figs 130–132 and 143)

Brightwell, *Remarks on the Genus Rhizosolenia*, 1858 *a*, p. 95, Pl. V, fig. 5 *e*; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil, 1, 1930 *b*, p. 586, fig 335; Allen and Cupp, *Plank. Diat. Java Sea*, 1935, p. 130, fig. 40.

Rhizosolenia polydactyla Castracane, *Diat Chall*, 1876, p 71, Pl. XXIV, fig 2; De Toni, *Syll. Alg.*, Vol II, 1891–94, p. 827.

Larger than the type, diameter 88–99 μ, length 448–1190 μ. Intercalary bands flat, punctate, punctæ 12 in 10 μ.

Distribution.—In the plankton of the European seas, particularly in the northern regions in quantities; Vancouver, California, West Indies, Antarctic, coast of Barbados, Java seas

48. *Rhizosolenia setigera* Brightwell

(Figs 137, 140 and 142)

Brightwell, *Remarks on the Genus Rhizosolenia*, 1858 *a*, p 95, Pl V, fig. 7; De Toni, *Syll Alg*, Vol II, 1891–94, p. 827; Van Heurck, *Traité des Diatomées*, 1899, p. 414, Pl. XVII, fig 602, Gran, *Nord Plank*, *Bot Teil*, Bd. VIII, 1908, p XIX 53, fig. 64; Boyer, *Syn N Am Diat*, 1926, p 100, Lebour, *Plank Diat N. Seas*, 1930, p 98; fig 70, Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930 *b*, p 588, fig 336, Allen and Cupp, *Plank Diat. Java Sea*, 1935, p. 129, fig. 37

Rhizosolenia Japonica Castracane, *Diat Chall*, 1876, p. 72, Pl XXIII, fig. 7.

Cells rod-shaped, cylindrical, 8 3 μ in diameter and up to 518 μ in length. Valves conical but slightly oblique Apical process long, hollow to some distance and ending in a long spine Intercalary bands scale-like, punctæ 18 rows in 10 μ.

Distribution.—In the European seas, particularly in the northern coast; Vancouver, California, Java Seas

49. *Rhizosolenia hebetata* (Bailey) Gran

var *semispina* (Hensen) Gran

(Figs 133–135 and 136)

Gran, *Nord. Plank*, *Bot. Teil*, Bd. VIII, 1908, p XIX 55, fig 67 *b*; Boyer, *Syn. N. Am Diat.*, 1926, p. 100 ; Lebour, *Plank Diat. N Seas*, 1930, p. 99, fig. 73 *a*; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p. 592, fig. 338; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 131, fig. 42.

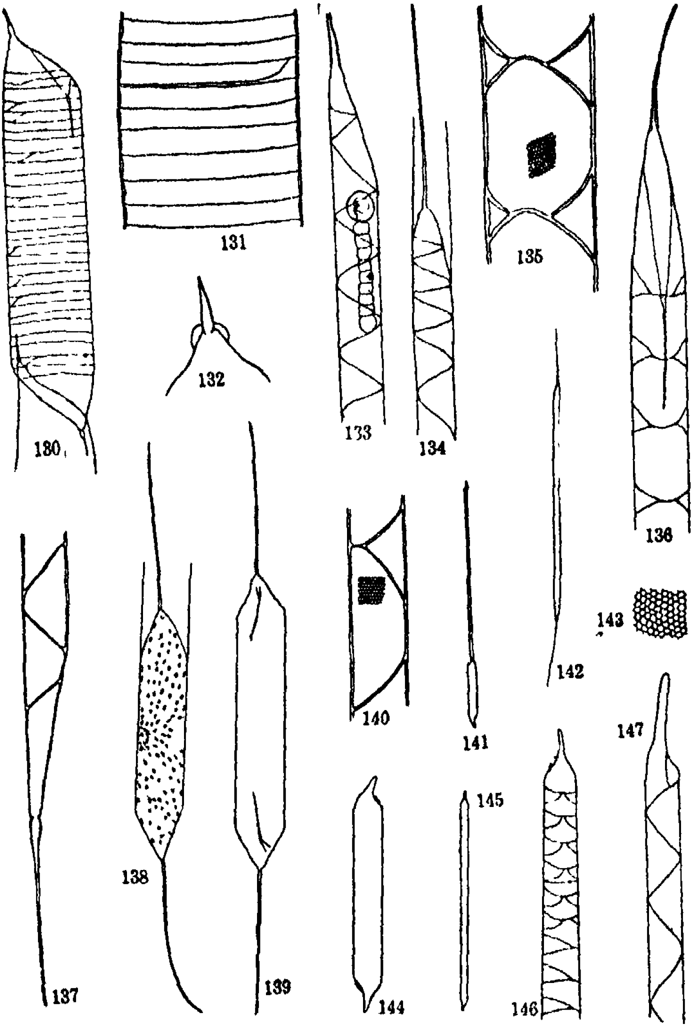
Cells longitudinally drawn out, length 224–560 μ, diameter 6-14 μ. Process long hollow at the base, ending in a long spine. Intercalary bands scale-like, pointed towards the apex, punctate, punctæ 18-24 in 10 μ The blue green, *Richelia intracellularis* often found inside the cell.

Distribution.—Arctic seas, East Greenland Sea, all parts of North Sea, Baltic, Skaggerak, English Channel, Belgian coast, Mediterranean, California, Antarctic.

50. *Rhizosolenia crassispina* Schroeder

(Figs. 138 and 139)

Schroeder, *Beiträge zur Kenntnis des Phytoplanktons warmer Meere*, 1906, p. 345, figs. 5 *a*, *b*, *c*.



TEXT-FIGS 130–147.—Figs. 130–132. *R stylıformis* var *latissima* Brightwell Fig. 130, ×150; Figs 131, 132, × 325 Figs. 133–135 *R hebetata* (Bailey) Gran var *semispina* (Hensen) Gran. Fig. 133, one end of cell with *Richelia* inside. × 460, Fig. 134, end of a daughter cell. ×460; Fig. 135, ×930 Fig. 136 *R. hebetata* var *semispina* (Hensen) Gran. ×460. Fig. 137. *R. setigera* Brightwell ×710. Figs 138–139. *R. crassispina* Schröder. ×150. Fig. 140. *R. setigera* Brightwell ×930. Fig. 141. *R alata* Brightwell. Auxospore. ×55. Fig. 142.

R. setigera Brightwell. × 150 Fig. 143. *R. styliformis* var *latissima* Brightwell Structure of intercalary band, × 930 Fig 144. *R alata* f. *indica* (Peragallo) Ostenfeld. Figs 145, 146 *R alata* Brightwell Fig 145, ×55, Fig. 146, ×150. Fig. 147. *R alata* f *gracillima* (Cleve) Grunow. ×710.

Cells cylindrical, straight, 42-51 μ broad Valves tapering Spires slightly constricted at the base, then broadened and then drawn out into a long hair-like process No visible structure on the valve or girdle Chromatophores numerous and disc-shaped.

Distribution.—Pacific Ocean

(i) *Alatæ*

51 *Rhizosolenia alata* Brightwell

(Figs 141, 145 and 146)

Brightwell, *Remarks on the Genus Rhizosolenia,* 1858 *a*, p 96, Pl V, fig 8, De Toni, *Syll Alg*, Vol II, 1891-94, p 830, Van Heurck, *Traité des Diatomées,* 1899, p 416, Pl XXXIII, figs 887, 888, Gran, *Nord Plank, Bot Teil,* Bd VIII, 1908, p XIX 56, fig 68, Boyer, *Syn N Am Diat*, 1926, p 100, fig 101; Lebour *Plank Diat N Seas,* 1930, p 88, fig. 60; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 600, fig 344; Allen and Cupp, *Plank Diat Java Sea,* 1935, p 131, fig 43

Cells rod-shaped, cylindrical, 7-29 μ in diameter and up to 644 μ in length. Valves shortly conical, ending in a tube-like more or less curved process; a small depression at the base of the tube into which the apex of the adjoining cell, if any, fits Intercalary bands scale-like, in two rows, no sculpturing visible on them.

Auxospores were observed

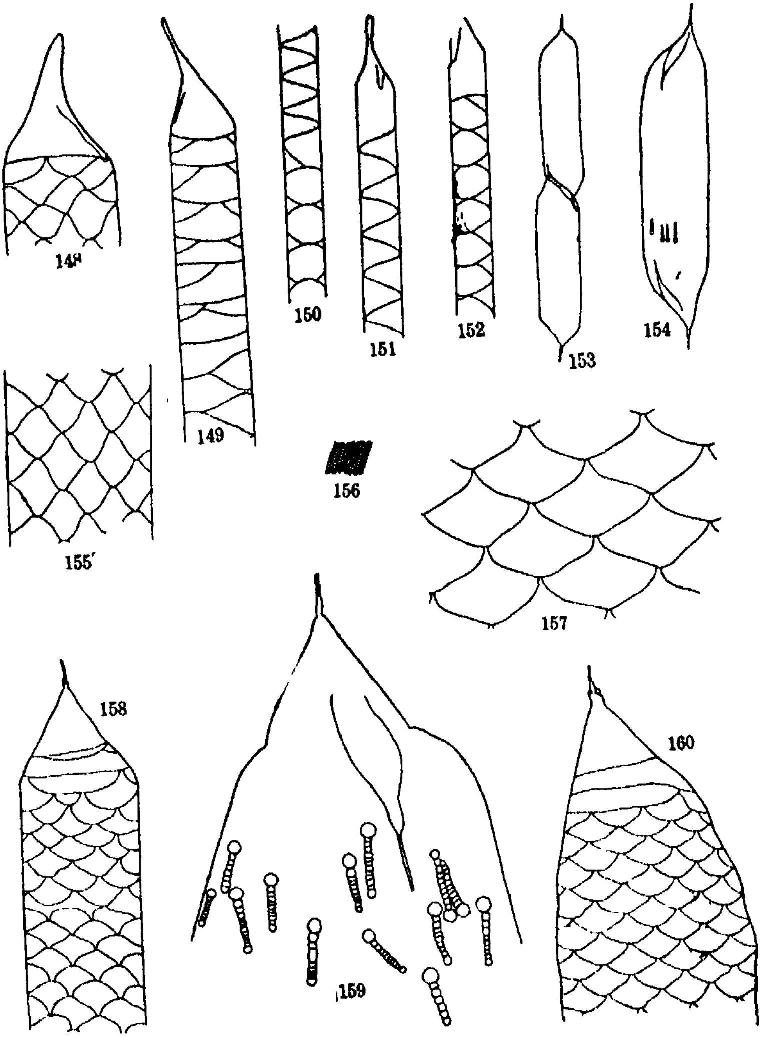
Rhizosolenia alata Brightwell forma *gracillima* (Cleve) Grunow

(Fig. 147)

Gran, *Nord. Plank., Bot Teil,* Bd VIII, 1908, p XIX 56, fig 68, d, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd, VII, Teil 1, 1930 *b*, p 601, fig. 345; Allen and Cupp, *Plank. Diat Java Sea,* 1935, p 131, fig 44

Rhizosolenia (*alata* var ?) *gracillima* Cleve, *On New and little known Diatoms,* 1881, p. 26, Pl IV, fig 78

Rhizosolenia alata var. *gracillima* (Cleve) Van Heurck, De Toni, *Syll. Alg.,* Vol. II, 1891-94, p. 830.



TEXT-FIGS 148–160.—Figs. 148–149. *R. alata* f. *indica* (Peragallo) Ostenfeld Fig. 148, ×220; Fig 149, ×325 Figs. 150–152. *R. alata* f *inermis* (Castracane) ×325. Figs. 153–154. *R* *Castracanei* var. nov. Figs 153, × 40; 154, × 55. Fig. 155. *R. alata* f. *indica* (Peragallo) Ostenfeld ×325. Figs. 156–160. *R. Castracanei* var. nov Fig. 156, structure of intercalary band. 159, note *Richelia*. Fig. 156, × 930; 157, ×325; 158, ×150; 159, ×215; 160, ×150.

Differs from the species in being very narrow, diameter 7μ or less, otherwise same.

Rhizosolenia alata Brightwell forma *indica* (Peragallo) Ostenfeld

(Figs. 144, 148, 149 and 155)

Gran, *Nord. Plank*, *Bot Teil*, Bd VIII, 1908, p. 56; Karsten, *Valdivian Expedn.*, 1907, p. 381, Taf XLI, fig 7; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930 *b*, p 602, fig. 346, Allen and Cupp, *Plank Diat. Java Sea*, 1935, p 131, fig. 45.

Differs from the species in its larger diameter, 33-111μ Process very striking curved. Intercalary bands variable.

Rhizosolenia alata Brightwell forma *inermis* (Castracane) Hustedt

(Figs. 150, 151 and 152)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b* p 602, fig. 348.

Rhizosolenia inermis Castracane, *Diat. Chall.*, 1876, p. 71, Pl. XXIV, figs 7, 8, 10 and 13

Rhizosolenia obtusa Hensen, Gran, *Nord Plank*, *Bot Teil*, Bd. VIII, 1908, p. XIX 56, fig 69

Similar to type, but with intercalary bands scale-like, scales keel-shaped. Diameter of cell 15-19μ

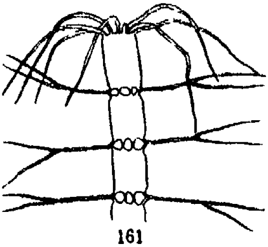
Distribution —In the Plankton of all seas, the larger form f. *indica* and the forms with strongly bent valves occur in the warmer seas; Mediterranean in Europe; those with bent and sharp valves, *e g.*, f. *inermis* in the colder seas.

SQUAMOSAE

52. *Rhizosolenia Castracanei* Peragallo var. *rhomboidea* var. nov.

(Figs. 153, 154 and 156-160)

Cells cylindrical, 126-210μ in diameter and 700-910μ in length. Intercalary bands arranged in several pervalvar series, scale like, rhomboidal to almost square in outline at the centre of the cell, sides slightly wavy. Calyptræ flat, somewhat obliquely cone-shaped, with very clear impression of the sister valve Process short, rather blunt, at the base with weakly differentiated ears. Cell-wall thin, sculpturing finer than in the type. Intercalary bands areolate-punctate, punctæ 20-24 in 10μ, arranged in three series system.



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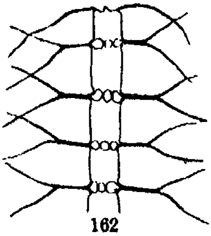

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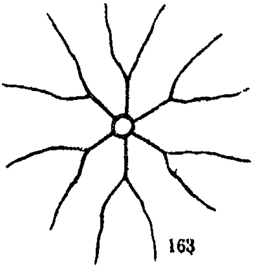

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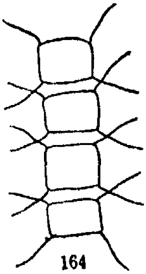

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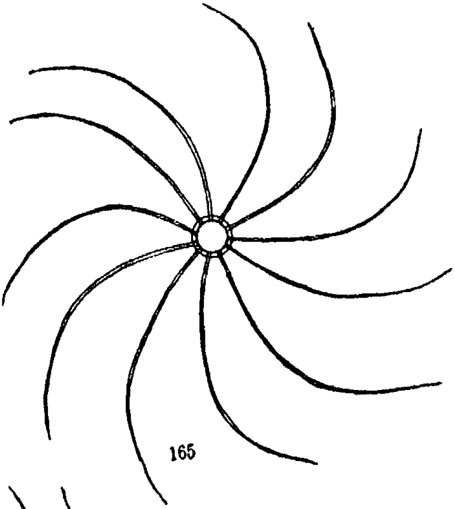

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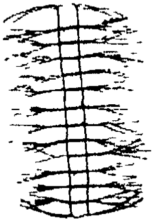

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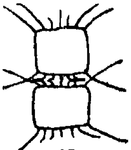

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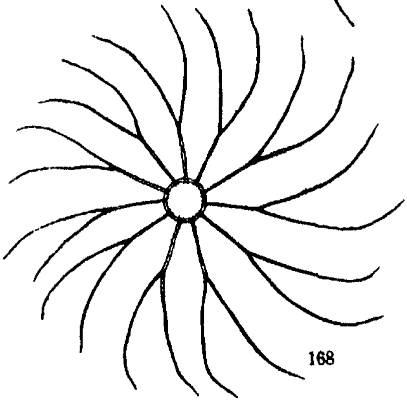

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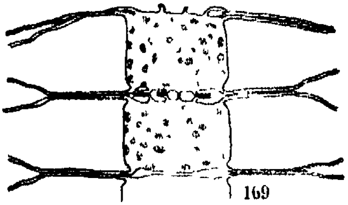

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TEXT-FIGS 161–169.—Figs. 161–163 *Bacteriastrum delicatulum* Cleve. Fig. 161, × 525; 162, ×460; 163, ×460. Fig. 164 *B. hyalinum* (?) Lauder. × 460. Fig. 165. *B. hyalinum* var.

princeps (Castracane) Ikari End cell, valve view. ×325 Fig 166. *B. hyalinum* Lauder. × 85. Fig. 167 *B hyalinum* (?) Lauder × 460 Fig 168 *B hyalinum* var. *princeps* (Castracane) Ikari. ×325. Fig 169 *B hyalinum* Lauder. Cells showing contents. ×460.

The present form resembles the species in almost all respects except in the shape and structure of the intercalary bands The intercalary bands in this are rhomboidal to almost square in outline, whereas in the type they are somewhat compressed The areolation in the present form is finer than in the type, there being 20–24 punctæ in 10 μ, whereas in the type there are only 9-10 in 10 μ

Distribution —Plankton of the Madras Coast.

Sub-order BIDDULPHIOIDEAE

Family Chætoceræ

XXII Genus *Bacteriastrum* Shadbolt

ISOMORPHA

53 *Bacteriastrum delicatulum* Cleve

(Figs 161–163)

Gran, *Nord Plank., Bot Teil*, Bd. VIII. 1908, p XIX 58, fig 72; Boyer, *Syn N. Am Diat*, 1927, p. 560, Labour, *Plank Diat N Seas*, 1930, p 82, fig. 55; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 612, fig, 353, Allen and Cupp, *Plank Diat Java Sea* 1935, p 132, fig 46.

Bacteriastrum curvatum Shadbolt, *New Forms of Diat*, 1854 *a*, p 14, Pl I, fig. 2.

Bacteriastrum furcatum Shadbolt, *ibid*, Pl. I, fig 1 ?

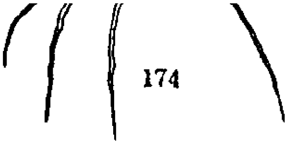
Cells longer than broad Setæ 8, perpendicular to chain axis, basal part long Apertures large Terminal setæ bent over the chain. Diameter of cell 11 μ.

Distribution —In the Atlantic and neighbouring seas; Mediterranean, La Jolla, California

54 *Bacteriastrum hyalinum* Lauder

(Figs 164, 166, 167, 169 and 173)

Lauder, *On new Diatoms*, 1864 *a*, p 6, Pl III, fig 3; Lebour, *Plank Diat. N. Seas*, 1930, p. 83, fig 56, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 615, fig 354, Allen and Cupp, *Plank. Diat. Java Sea*, 1935, p 132, fig. 47



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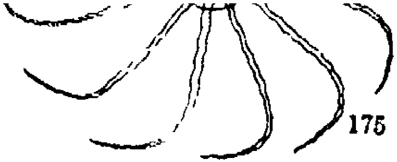

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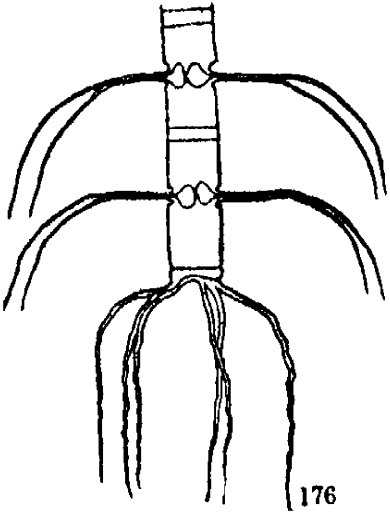

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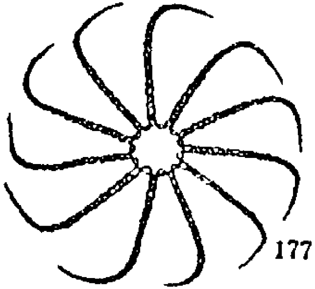

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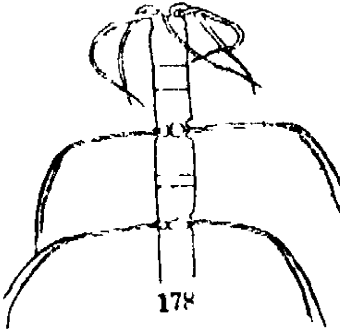

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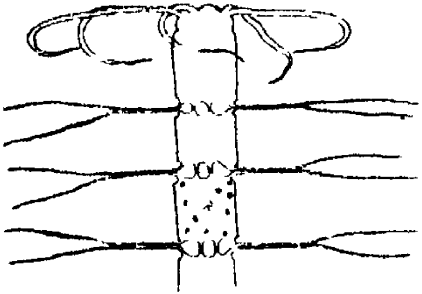
TEXT-FIGS. 170–178.—Fig 170–172. *B varians* Lauder. Figs. 170, × 460, 171, × 710; 172, × 220. Fig. 173 *B. hyalinum* Lauder. × 350 Fig 174. *B. elegans* Pavillard × 460. Fig. 175. *B. varians* Lauder. End cell, valve view × 460 Figs. 176–178. *B. cosmosum* Pavillard. Fig. 176, ×460, 177, end cell, valve view, ×325; 178, ×460.



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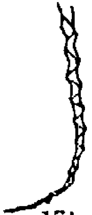

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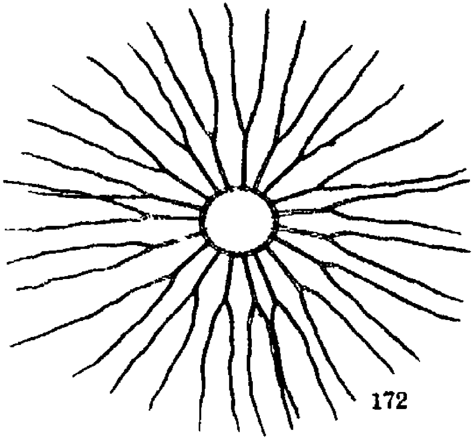

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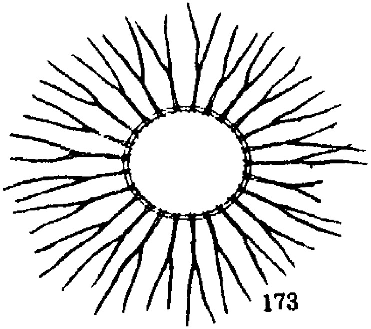

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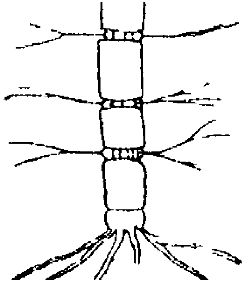
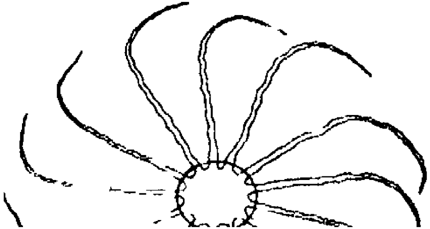




Cells flat, broader than long, diameter 37 μ. Setæ numerous (24), basal part short. Terminal setæ bent over chain axis.

Bacteriastrum hyalinum Lauder

var. *princeps* (Castracane) Ikari

(Figs. 165 and 168)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 615, fig. 355

Bacteriastrum varians var *princeps* Castracane, *Diat Chall*, 1876, p. 84, Pl. XIV, fig 2; Pl XXIX, fig 3.

Differs from the species in the strong spirally twisted nature of the spines of the inner cells of the chain Diameter of cells 18–29 μ.

Distribution.—In the north Atlantic ocean, frequent on the northern coast of middle Europe; Mediterranean; var. *princeps* only in the warmer seas, Mediteranean in Europe.

55 *Bacteriastrum varians* Lauder

(Figs. 170–172 and 175)

Lauder, *On New Diatoms*, 1864 *a*, p 8, Pl III, figs 1–6, Karsten, *Valdivian Expedn*, 1907, p 170, Taf XXXIV, figs 1, 1*a*, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 616, fig 356; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 133, fig. 48.

Bacteriastrum furcatum Shadbolt, *New Forms of Diat*, 1854 *a*, p 14; Boyer, *Syn. N. Am Diat*, 1926, p 114

Chætoceros (*Bacteriastrum*) *varians* Van Heurck, *Traité des Diatomées*, 1899, p. 422, Pl XVIII, fig 605

Cells 12–37 μ in diameter Setæ 8 to 19, at right angles to the chain axis Terminal setæ with fine spines arranged in spiral rows.

Auxospores were observed

Distribution.—Only in the warmer seas, not in Europe.

Sagitta

56 *Bacteriastrum elegans* Pavillard

(Fig. 174)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 621, fig. 360.

Cells cylindrical, 10–21 µ in diameter, forming many celled chains with more or less clear apertures Inner spines perpendicular to the chain axis with short basal part Outer valve asymmetrical and unlike others owing to the presence of a clear ring-like furrow. Processes of posterior valve directed in such a way that they enclose a bell-shaped space. Processes robust with spirally arranged minute spines.

Distribution —Pelagic in the Mediterranean region

57 *Bacteriastrum cosmosum* Pavillard

(Figs. 176–178)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p. 622, fig 361; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 133, fig. 50

Cells cylindrical, 9–19 µ in diameter, forming long chains with more or less wide apertures Inner setæ with short basal part perpendicular to the chain axis, at bifurcation bent towards posterior end of the chain and parallel to the chain axis Anterior terminal setæ curved and directed towards the posterior, with spirally arranged spines Posterior terminal setæ thicker than others Setæ 6–11 End valves of both anterior and posterior terminal cells with a deep furrow

Distribution —Mediterranean and Java Sea

XXIII. Genus *Chætoceros* Ehrenberg

Sub-genus *Phæoceros* Gran

Borealia

58 *Chætoceros Eibenii* Grunow

(Figs 179–181)

Lebour, *Plank Diat N Seas*, 1930, p 116, fig 82; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd , VII, Teil 1, 1930 *b*, p 653, fig 369; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 135, fig 51

Chætoceros paradoxus var. *Eibenii* Van Heurck, *Traité des Diatomées*, 1899, p 422, Pl XXXV, fig 916

Cells cylindrical forming straight chains, 32–50 µ in diameter. Apertures elliptical. Tiny spine at the centre of the valve Setæ arising from the inner valve surface, base of setæ short Chromatophores numerous, disc-shaped, distributed in the cell and also in the setæ.

Distribution.—Coastal plankton of Europe, Japanese Sea and Java Sea.

59. *Chætoceros coarctatus* Lauder

(Figs 182–187)

Lauder, *Diat Hong Kong*, 1864 *b*, p 79, Pl VIII, fig 8; Cleve, *Diat Sea of Java*, 1873 *a*, p 9, Pl II, fig 10 *a*, *b*, *c*, De Toni, *Syll Alg.*, Vol. II, 1891–94, p. 996; Karsten, *Valdivian Expedn*, 1907, Taf XXXI, fig 3; Gran, *Nord. Plank*, *Bot. Teil*, Bd VIII, 1908, p. XIX 68, fig 80; Boyer, *Syn. N Am Diat*, 1926, p 113, Lebour, *Plank Diat N Seas*, 1930, p. 119, fig. 55; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd, VII, Teil, 1, 1930 *b*, p. 655, fig 370; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 135, fig 52

Cells cylindrical with elliptical valvar plane, apical axis 35–49 μ in length, cells united in straight chains which have a very robust appearance Mantle with deep, clear, ring-like furrow. Outer setæ of the end cells different. Posterior terminal setæ much thicker than the rest, ridged with minute spines; anterior ones less robust, spined and curved towards posterior end. Inner setæ resembling the anterior ones. Chromatophores numerous, disc-shaped.

A member of the *Vorticellæ* is usually seen attached to the cells on the outside.

Distribution —Preponderating in tropical waters, in Europe only in the Mediterranean. Northern limit is about 47° N latitude.

60 *Chætoceros denticulatum* Lauder

(Figs 188–190)

Lauder, *Diat Hong Kong*, 1864 *b*, p 79, Pl VIII, fig 9, De Toni, *Syll Alg*, Vol. II, 1891–94, p 995; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 135, fig 53.

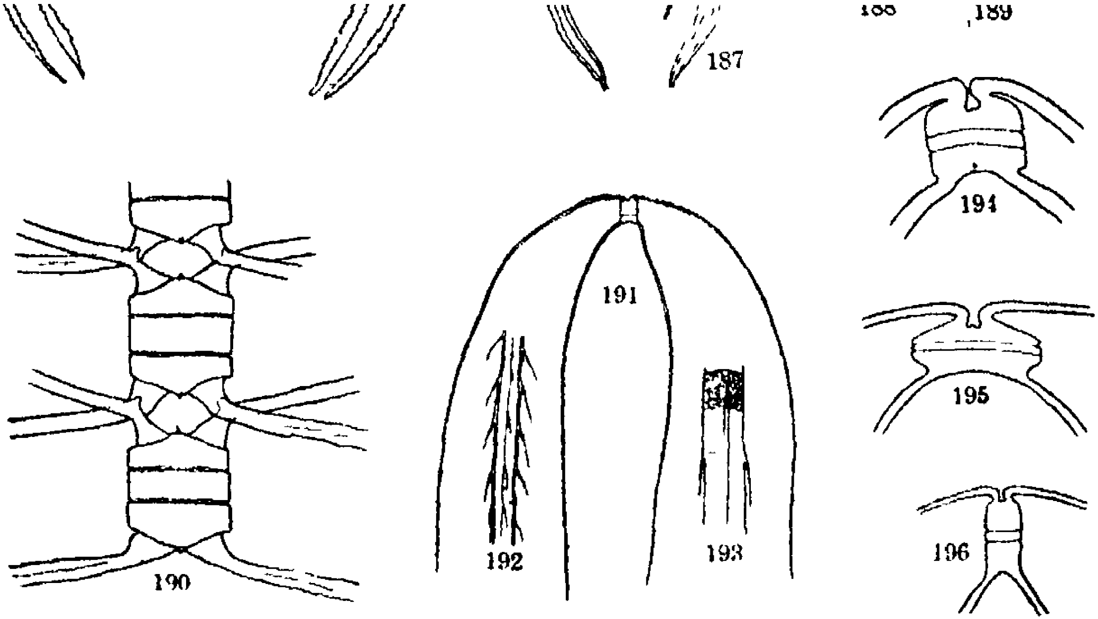
Cells cylindrical forming straight chains Apical axis 21–32 μ Apertures small, vertically rhombic. Base of setæ directed almost vertically, with a small tooth on the inner side Setæ spinous and striated. A very small spine present at the centre of the valve

Distribution.—Hong Kong and Java Sea.

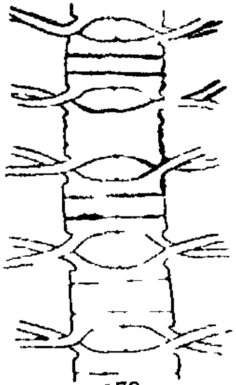
61. *Chætoceros peruvianus* Brightwell

(Figs 191–196)

Brightwell, *On filamentous and long-horned Diat*, 1856 a, p 107, Pl VII, figs. 16–18; *Further observ Triceratium and Chætoceros*, 1858 *b*, Pl VIII, figs. 9 and 10; De Toni, *Syll Alg*, Vol. II, 1891–94, p 991; Gran, *Nord.*



Text-Figs. 179–196 Figs. 179–181. *Chætoceros Eibenii* Grunow. Fig. 179, ×328; 180, × 710; 181, cross-section of seta, × 710 Figs. 182–187 *Ch. coarctatus* Lauder. Fig. 182, ×150; 183, ×710, 184, ×710; 185, × 328, 186, valve view of cell, × 328; 187, × 150. Figs. 188–190. *Ch. denticulatum* Lauder. Fig. 188, 189, × 710, 190, × 460. Figs. 191–196. *Ch. peruvianus* Brightwell. Fig. 191, ×150; 192, 193, ×930; 194–196, ×460.



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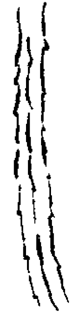

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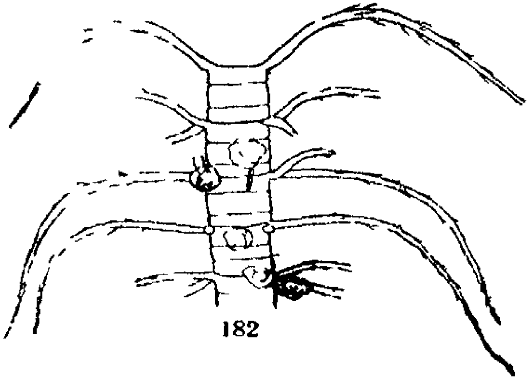

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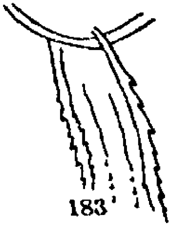

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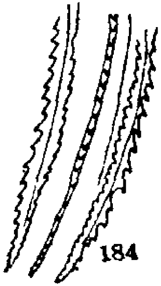

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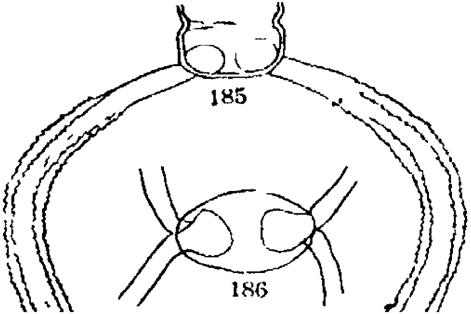

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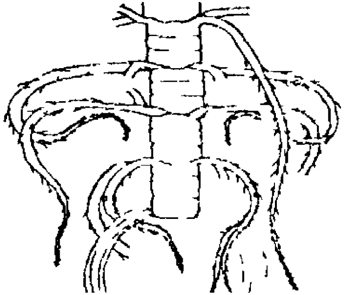
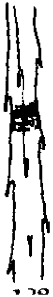
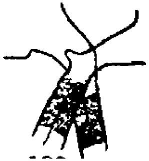






Plank, *Bot. Teil*, Bd. VIII, 1908, p XIX 70, fig. 84; Boyer, *Syn. N. Am. Diat*, 1926, p. 106; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p. 671, fig. 380; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 136, fig. 56

Cells single, very rarely forming chains of two or three cells Apical axis 9–31 µ in length Valves dissimilar The upper rounded, the lower flat; both with equally developed valve-mantle whose height varies extraordinarily. Setæ of upper valve starting from near the centre of the valve, after short basal part turning sharply and running backward in wide outwardly convex curves; at the end more or less divergent to convergent. Setæ of lower valve starting near the margin, slightly convex towards outside and then running almost parallel to the pervalvar axis Setæ strong, four cornered, spined and striated, striæ 18-25 in 10 µ. Chromatophores numerous, small and disc-shaped present in the setæ also.

Chætoceros peruvianus Brightwell

forma *robusta* (Cleve) Hustedt

(Figs 200 and 201)

Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd VII, Teil 1, 1930 *b*, p 673, fig. 381 *a*; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 137, fig. 57

Chætoceros peruvianus var *robutsa* Cleve, *Diat Sea of Java*, 1873 *a*, p. 9, Pl. II, fig. 8

Differs from the type in possessing very robust setæ which are more closely spined than in the type.

Distribution.—In the warmer seas widely distributed; in Europe in the Mediterranean. Atlantic and Pacific oceans, Java Sea; Peruvian guano.

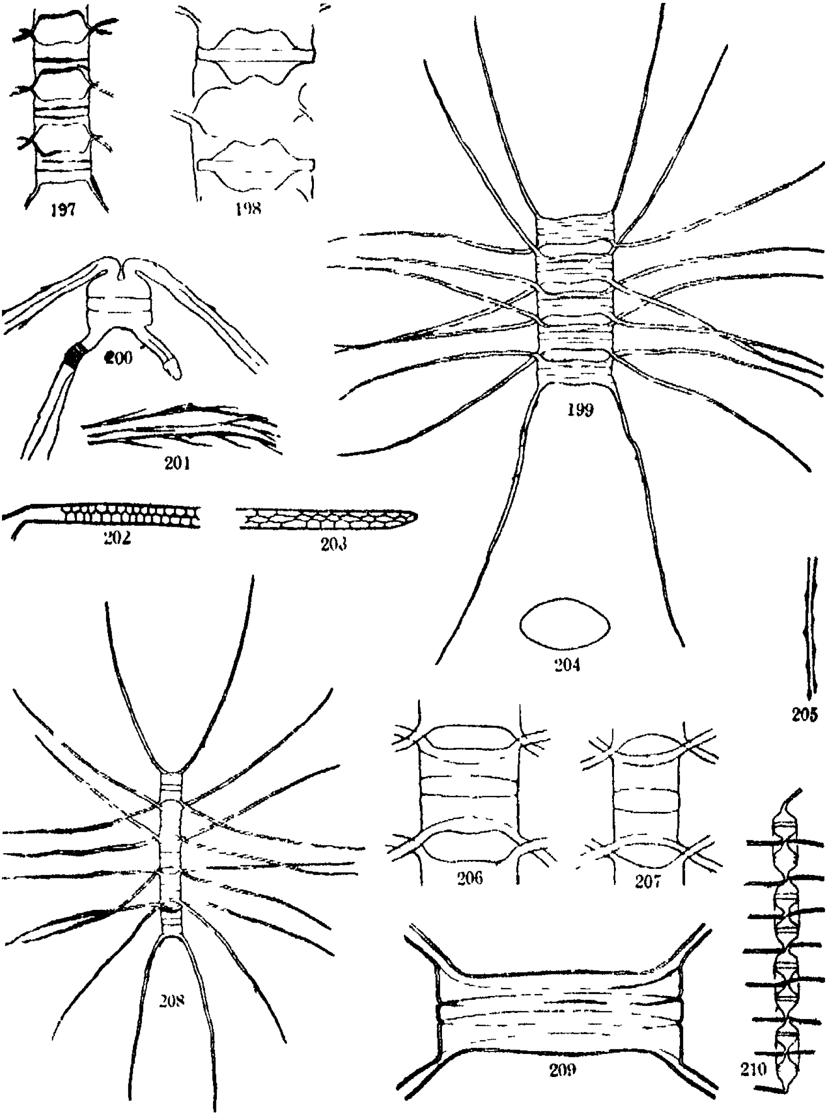
Sub-genus *Hyalochæte*

Dicladia

62. *Chætoceros Lorenzianus* Grunow

(Figs. 198–199, 202–204, 206–209)

De Toni, *Syll Alg*, Vol. II, 1891–94, p. 994; Gran, *Nord. Plank*, *Bot Teil*, Bd. VIII, 1908, p. XIX, 76, fig 90, Boyer, *Syn N Am. Diat*, 1927, p. 561; Lebour, *Plank Diat. N Seas*, 1930, p 128, fig. 93; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 679, fig. 385; Allen and Cupp, *Plank. Diat. Java Sea*, 1935, p. 137, fig 58.



TEXT-FIGS 197–210.—Fig 197 *Chætoceros indicus* sp nov. × 328. Figs. 198–199. *Ch. Lorenzianus* Grunow. Fig. 198, ×460; 199, ×215. Figs. 200–201. *Ch. peruvianus* f. *robusta*

Cleve.) Hustedt Fig. 200, ×460, 201, ×930 Figs. 202–204. *Ch. Lorenzianus* Grunow. 202, base; and 203, distal end, 204, cell in valve view, × 930. Fig. 205. *Ch. indicus* sp nov. × 930. Figs 206–209 *Ch Lorenzianus* Grunow Fig. 206, 207 and 209, × 710, 208, × 220. Fig. 210 *Ch indicus sp.* nov. × 215

Chætoceros cellulosus Lauder, *Diat Hong Kong*, 1864 *b*, p 78, Pl. VIII, fig. 12.

Cells of apical axis 16–58 μ long, forming straight chains. Apertures of varying sizes Setæ springing from the corners with a very short basal part. Terminal setæ thicker and somewhat shorter than the others, slightly diverging at the base and then running parallel to the chain axis. Setæ four-sided, punctate-areolate, punctæ of neighbouring faces alternating with each other. Resting spore with processes only on one valve which spring near the centre of the valve; the other valve somewhat bilobed.

In the figure given by Hustedt the processes of the resting spore spring more towards the sides of one of the valves and the other valve is not so clearly bilobed Probably the resting spores observed here are not mature

Distribution.—In the warmer seas widely distributed in the coastal plankton, in Europe common along the coast of south Europe, in the Mediterranean common. Sparsely distributed along the north coast of middle Europe; La Jolla, Java Sea

63 *Chætoceros indicus* sp nov

(Figs 197, 205 and 210)

Cells forming straight chains, apical axis measuring 18-26 μ. Apertures of varying sizes, setæ springing from the corners with minute spines spirally arranged on them

The cells resemble *Ch. Lorenzianus* in their broad girdle view but are Madgeburgh-sphere-shaped in their narrow girdle view Again, the setæ have minute spines spirally arranged on them as in *Ch. Eibenii* and *Ch. Lauderi* unlike in *Ch. Lorenzianus* where they are areolate-punctate.

Distribution —Plankton of the Madras coast.

Cylindrica

64 *Chætoceros Lauderi* Ralfs

(Figs 211–213, Pl II, fig 3)

Ralfs, in Lauder, *Remarks on Marrine Diatomaceæ, etc*, 1864, p. 77, Pl. VIII, figs. 3 and 4, De Toni, *Syll Alg*, Vol II, 1891-94, p. 995;

Lebour, *Plank. Diat. N. Sea,* 1930, p. 131, fig. 95; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b,* p. 683, fig. 387; Allen Cupp, *Plank. Diat Java Sea,* 1935, p 138, fig 59.

Chætoceros Weissflogii Schütt, Gran, *Nord Plank*, *Bot. Teil,* Bd VIII, 1908, p. XIX 77, fig 92

Cells cylindrical, valves almost round, tender, forming chains apical axis 16-29 μ. Apertures narrow and elliptical. Setæ with small spines arranged spirally. Resting spores with strongly curved primary valve, spinous on the upper part and with numerous needle-like processes at the margin

Distribution—Mainly in the warmer seas, in Europe in the southern part of North Sea, Skaggerak, Baltic, English Channel, Belgium coast, Java Sea

Compressa

65 *Chætoceros compressus* Lauder

(Figs. 218)

Lauder, *Diat Hong Kong,* 1864 *b,* p. 78, Pl. VIII, fig 6; Boyer, *Syn. N Am Diat*, 1927, p 561, Lebour, *Plank Diat N Seas,* 1930, p. 132, fig. 96, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b,* p 684, fig 388; Allen and Cupp, *Plank Diat Java Sea,* 1935, p. 138, fig 60.

Chætoceros contortum Schutt, Gran, *Nord Plank*, *Bot Teil,* Bd. VIII, 1908, p XIX 78, fig 93

Cells forming long chains, apical axis 7 5–18 μ in length. Apertures somewhat wide, sometimes a mere slit The setæ of some cells in a chain more robust, thickened and bent to run parallel to the chain axis. Setæ slightly twisted spirally, spinous The other setæ thin. Chromatophores many, disc-shaped

Distribution.—Very common in all European seas, from the tropics to the Polar seas; Hong Kong, California, Indian Ocean and Java Sea.

Protuberantia

66 *Chaetoceros didymus* Ehrenberg

(Figs 214 and 215)

De Toni, *Syll Alg*, Vol II, 1891–94, p. 997; Gran, *Nord. Plank*, *Bot. Teil,* 1908, p XIX 79, fig 94; Boyer, *Syn. N Am. Diat*, 1926, p. 107; Lebour, *Plank. Diat. N. Seas,* 1930, p. 133, fig. 97; Hustedt, Rabenhorst's

Kryptogamen-Fl., Bd VIII, Teil 1, 1930 *b*, p 688, fig. 390; Allen and Cupp, *Plank Diat. Java Sea*, 1935, p 138, fig. 61

Cells forming straight chains, apical axis of the cells 24–39 µ in length. Transapical axis shorter than apical axis A semicircular knob or protuberance present in the middle of the valve Setæ arising from the corners of the adjacent cells crossing farther out Chromatophores two, plate-like.

Chaetoceros didymus Ehrenberg

var *protuberans* (Lauder) Gran *et* Gendo

(Fig 216)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 690, fig 392, Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 139, fig 62

Chaetoceros protuberans Lauder, *Diat Hong Kong*, 1864 *b*, Pl VIII, fig 11

Similar to type The terminal setæ slightly thicker than the others and more divergent than in the type Apical axis 15 µ in length

Distribution —The type neritic in all the seas, Arctic and Atlantic Oceans; Peruvian guano. Var *protuberans* principally in the warmer seas in Europe in the Mediterranean; Java Sea

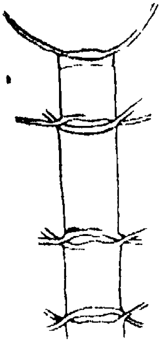
Chætoceros didymus Ehrenberg var *heterosetoides* var nov

(Fig 220)

Cells forming straight chains, apical axis measuring 14 5 µ in length. Transapical axis shorter than apical axis. A semi-circular knob or protuberance present in the middle of the valve. Setæ arising from the corners of adjacent cells, crossing farther out Some of the setæ of the inner cells thicker and running parallel to the axis of the chain and directed toward one end of the chain Chromatophores two and plate-like.

This form resembles the type in all respects excepting for the nature of some of the setæ which resemble those of the inner cells of *Ch compressus* in being thicker and directed toward one end of the chain and running somewhat parallel to the chain axis

Distribution.—Plankton of the Madras coast.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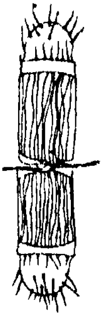
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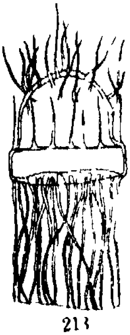
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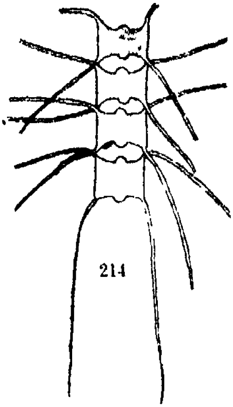
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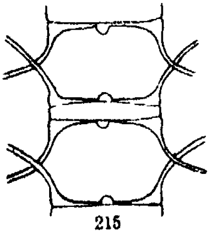
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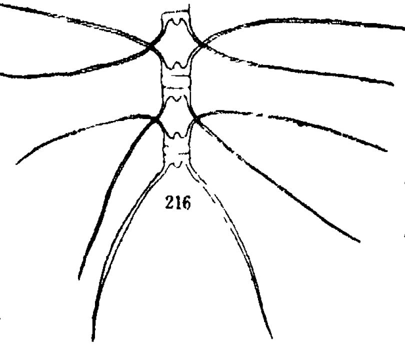
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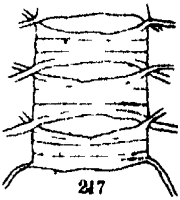
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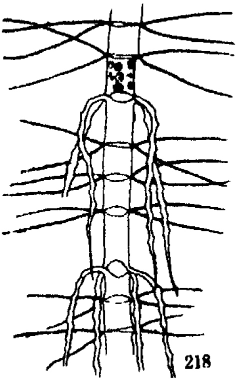
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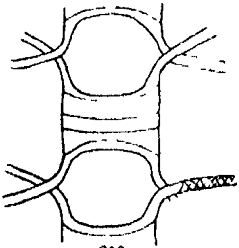
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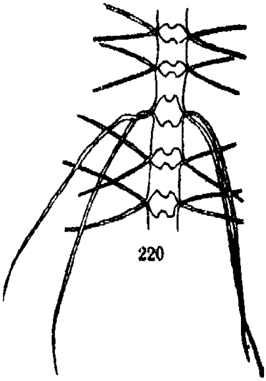
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Text-Figs 211–220—Figs 211–213 *Chætoceros Lauderi* Ralfs Fig 211, ×325, 212, two resting spores in a cell, × 460, 213, a resting spore, × 930 Figs 214–215, *Ch. didymus*

Ehrenberg. Fig 214, ×328, 215, ×460 Fig 216 *Ch didymus* var *protuberens* (Lauder) Gran *et* Yendo ×328 Fig 217 *Ch Van Heurckii* Gran ×325 Fig 218 *Ch compressus* Lauder × 365 Fig 219 *Ch Van Heurckii* Gran × 460 Fig 220 *Ch didymus* var, *heterosetoides* var nov × 328

Constricta

67 *Chætoceros Van Heurckii* Gran

(Figs 217 and 219)

Karsten, *Valdivian Expedn*, 1907, p 391, Taf XLIV, fig 6*a*; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 139, fig 65.

Cells forming straight chains, apical axis 24–58 μ. Valves slightly constricted in the middle. Apertures narrow, elliptic Setæ more or less curved towards one end of the chain, slightly spinous

Distribution.—Indian Ocean and Java Sea

Stenocincta

68 *Chætoceors affinis* Lauder

(Figs. 221–227)

Lauder, *Diat. Hong Kong*, 1864 *b*, p 78, Pl VIII, fig 5, De Toni, *Syll Alg.*, Vol II, 1891–94, p 996, Lebour, *Plank Diat N Seas*, 1930, p 135, fig. 99, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 695, fig 396, Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 140, fig 66

Chætoceros javanicus Cleve *Diat Sea of Java*, 1873 *a*, p. 10, Pl. II, fig. 13.

Chætoceros Schüttii Cleve, *Plank Cilico Diat*, 1894–95, p. 14, Pl I, fig. 1; Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX, 81, fig. 97

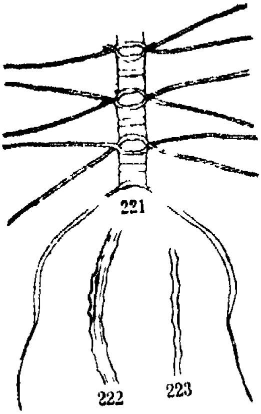
Chætoceros Ralfsii Karsten, *Valdivian Expedn*, 1907, Taf XXXIII, figs 17, 18

Chains straight, apertures narrow, apical axis of cells 8–18 μ in length Terminal setæ strongly divergent, thicker than the rest with spines arranged spirally. Resting spore formed in the middle of the cell, covered with numerous small spines Chromatophore one, plate-like.

Chætoceros affinis Lauder var. *intermedius* var nov.

(Fig. 233)

Cells forming straight chains, apertures narrow; apical axis measuring 5 5–8 μ in length Setæ almost of the same size becoming hair-like



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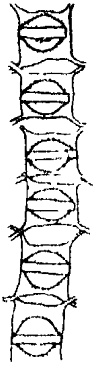

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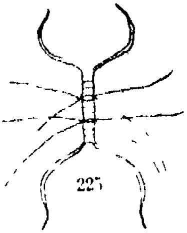

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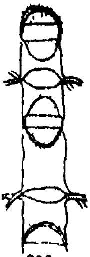

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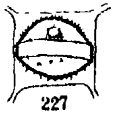

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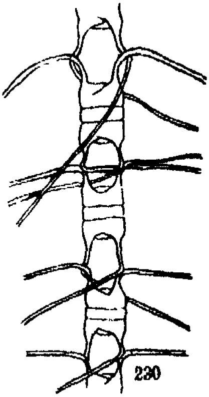

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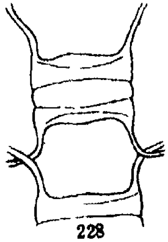

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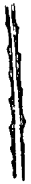

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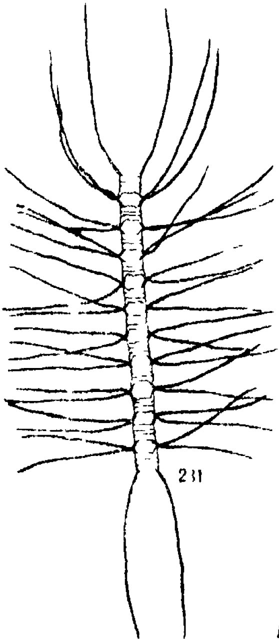

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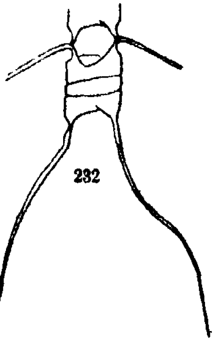

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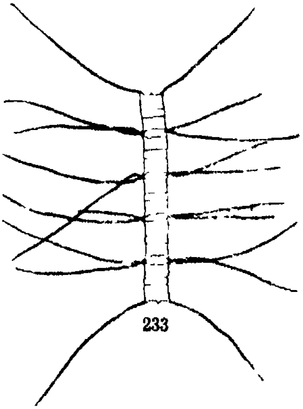

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Text-Figs 221-233.—Figs 221-227. *Ch. affinis* Lauder Figs. 224 and 226 with resting spores; 227, a single resting spore, 221, × 460; 222, 223, 224, 226 and 227 × 710; 225, × 183-

Figs. 228–229. *Ch lascinosus* Schütt. 228, ×710, 229, ×930 Fig 230 *Ch paradoxum* Cleve. × 710. Fig. 231. *Ch lascinosus* Schütt × 130 Fig 232 *Ch paradoxum* Cleve. × 710 Fig 233. *Ch affinis* var *intermedius* var nov ×460

toward the distal end and slightly curved at the end. Chromatophore one, plate-like

The cells resemble those of the type and *Ch affinis* var *circinalis* (Meunier) Hustedt (1930 *b*, p. 697, fig 397) but very closely the latter; however, differs in not having the setæ so strongly curved as in the variety and the end setæ not being different from the inner ones which is the case in the type.

Distribution —In most seas, frequent in certain regions. Var. *intermedius* var nov in the Madras coast

69 *Chætoceros paradoxum* Cleve

(Figs. 230 and 232)

Cleve, *Diat Sea of Java,* 1873 *a*, p 10, Pl III, fig 16, De Toni, *Syll Alg*, Vol. II, 1891–94, p. 992, Van Heurck, *Traité des Diatomées,* 1899, p. 422; Allen and Cupp, *Plank Diat Java Sea,* 1935, p 140, fig 67

Chætoceros diadema (Ehrenberg) Gran, Boyer, *Syn N Am Diat*, 1926, fig 109.

Cells forming chains, chains twisted Cell wall thick. Girdle bands deeply constricted. Apertures large. Apical axis of the cells 8–18 μ

Distribution.—River Dee in England, Java.

Lascinosa

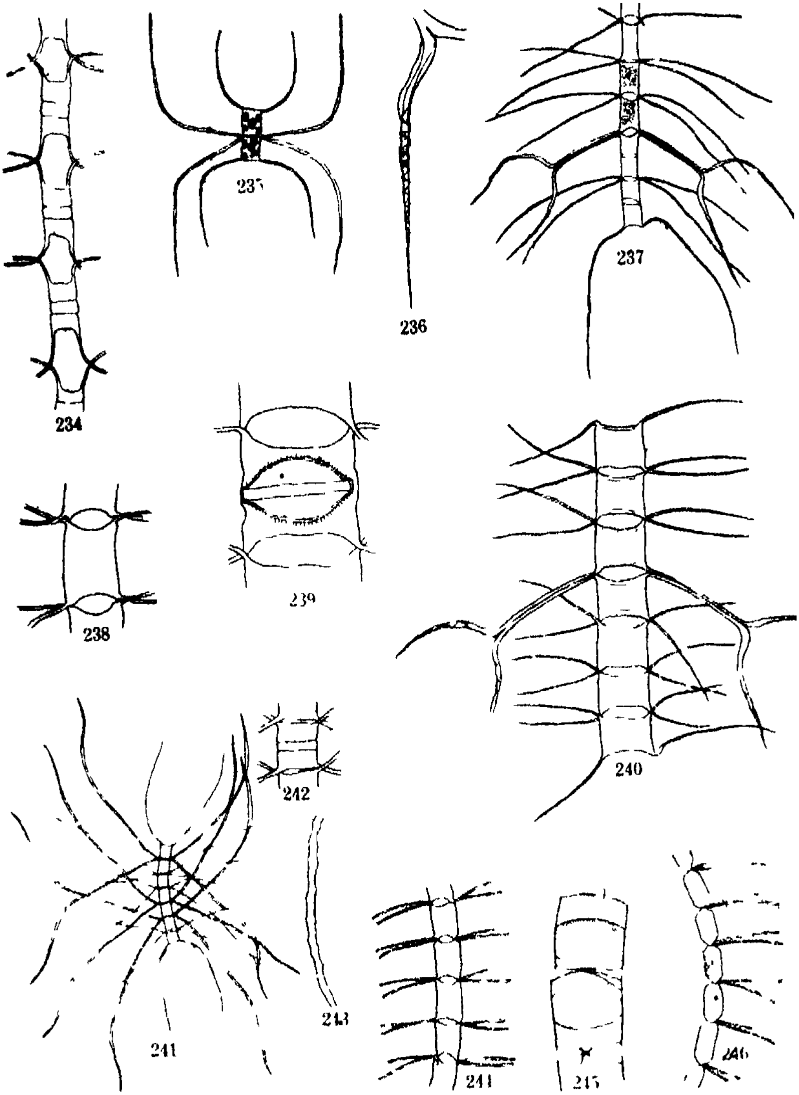
70 *Chætoceros lascinosus* Schutt

(Figs. 228, 229 and 231)

Gran, *Nord Plank*, *Bot Teil,* Bd. VIII, 1908, p XIX 82, fig 99. Boyer, *Syn N. Am. Diat*, 1927, p 561; Lebour, *Plank Diat N. Seas,* 1930, p 137, fig 100; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 701, fig. 401 *a*, Allen and Cupp, *Plank Diat Java Sea,* 1935, p 141, fig. 69.

Chætoceros distans Cleve, *Plank. Cilico. Diat*, 1894–95, p. 14, Pl II, fig. 2.

Cells forming straight chains, apical axis 11–24 μ in length. Apertures long and somewhat oblong. Setæ thin, basal part somewhat parallel to



TEXT-FIGS 234-246 — Fig. 234 [illegible] × 710. Fig. 235. *Ch diversus* Clev ×220. Figs. 236-237 *Ch messanensis* Castracane. Fig. 236, × 710; 237, × 220 Fig. 23

Chætoceros curvisetus **Cleve, × 710 Fig 239 *Ch holsaticus* Schütt, with resting spore × 710 Fig. 240 *Ch. messanensis* Castracane ×460 Figs. 241-243 *Ch diversus* Cleve Fig. 241, a chain, × 220, 242, a cell, × 710, 243, spine, × 710 Figs 244-246 *Ch curvisetus* Cleve Fig. 244, ×325, 245, formation of resting spores, ×710, 246, ×325**

the chain axis Terminal setæ somewhat thicker and more or less parallel to the chain axis Chromatophores two plates in each cell

Distribution.—Atlantic coast of Europe, Arctic Sea, Davis Strait, Norwegian Sea, Baltic Sea, North Sea, Mediterranean, Atlantic plankton, California and Java Sea.

71 *Chætoceros pelagicus* Cleve

(Fig 234)

Cleve, *Diat Arctic Sea*, 1873 *b*, p 11, Pl I, fig 4, De Toni, *Syll Alg*, Vol. II, 1891-94, p 993; Gran, *Nord*, *Plank*, *Bot Teil*, Bd VIII, 1908, p. XIX 83, fig 101; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 704, fig. 402.

Chætoceros Ostenfeldii Cleve, *Notes Atlantic Plank*, 1900, p 21, Pl VIII, fig 19.

Cells built on the same plan as the former; apical axis 6 5 μ in length forming chains Apertures large, oblong. Setæ not strong Chromatophore one in each cell

Distribution —In the coastal region of North Atlantic Ocean

Diadema

72 *Chætoceros holsaticus* Schütt

(Fig. 239)

Gran, *Nord Plank.*, *Bot Teil*, Bd VIII, 1908, p. XIX 85, fig 105, Lebour, *Plank Diat N. Seas*, 1930, p 142, fig. 104, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 714, fig 407

Cells forming straight chains, apical axis 26 5 μ in length. Apertures large. Resting spore formed one in each cell Valve of resting spore arched and spinous.

Distribution.—Neritic in the coastal region of Europe, frequent in brackish-water regions in the north; characteristic for the East Sea region Danish waters. Gulf of Finland, Bothnia.

Diversa

73. *Chætoceros diversus* Cleve

(Figs 235, 241–243)

Cleve, *Diat. Sea of Java*, 1873 *a*, p 9, Pl II, fig 12, De Toni, *Syll. Alg.*, Vol II, 1891–94, p. 991, Karsten, *Valdivian Expedn*, 1907, Taf XXXIII, fig 19, Gran, *Nord Plank*, *Bot Teil*, 1908, p XIX 87, fig. 107, Lebour, *Plank Diat. N. Seas*, 1930, p 147, fig 108, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 716, fig. 409, Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 142, fig. 71

Cells with apical axis measuring 5–8 μ in length, forming straight chains which are usually short. Apertures very small Setæ, some hair-like; others thicker, tubular and spinous. Terminal setæ thin and hairlike.

Distribution—Tropical and sub-tropical; in Europe only in the Mediterranean North Sea, northern limit according to Gran 40° N

74 *Chætoceros messanensis* Castracane

(Figs 236, 237 and 240)

Karsten, *Valdivian Expedn*, 1907, p 169, Taf XXXII, fig 13, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 718, fig 410

Chætoceros sp Lauder, *On New Diat*, 1864 *a*, Pl III, fig 8

Chætoceros furca Cleve, Gran, *Nord Plank*, *Bot. Teil*, Bd. VIII, 1908, p. XIX 87, fig 108, Lebour, *Plank. Diat N. Seas*, 1930, p. 146, fig. 107

Cells forming long straight chains, apical axis 12–39 μ in length. The corners of adjacent cells touching each other Apertures round to elliptical. Bristles usually thin, some of the setæ robust, the basal part of two such setæ running closely adpressed to each other and forking farther out, spinous, the spines arranged spirally. End bristles diverging, unlike each other Chromatophore a single plate

Distribution—Tropical and sub-tropical; in Europe in the Mediterranean

Brevicatenata

75 *Chætoceros Wighami* Brightwell

(Fig. 247)

Brightwell, *On filamentous and long-horned Diatomaceæ*, 1856 *a*, p. 108, Pl. VII, figs. 19–36; Gran, *Nord Plank*, *Bot Teil*, Bd. VIII, 1908, p. XIX

88, fig. 111; Boyer, *Syn N Am. Diat*, 1926, p 111; Lebour, ***Plank. Diat. N. Seas***, 1930, p 149, fig. 111, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 1, 1930 *b*, p 724, fig 414

Cells somewhat tender forming chains, apical axis measuring 10–18 μ. Cells in broad girdle view oblong with sharp corners, the corners of neighbouring cells touching each other and enclosing a narrow slit-like aperture. Setæ thin and fragile Inner ones perpendicular to the chain axis; end setæ more or less parallel to the chain axis Chromatophore plate-like.

Distribution —North Atlantic, Davis Strait, Danish Sea, Skaggerak, Baltic, English Channel, Mediterranean

Curviseta

76 *Chætoceros curvisetus* Cleve

(Figs 238, 244–246)

De Toni, *Syll Alg*, Vol II, 1891–94, p 992, Gran, *Nord Plank*, ***Bot Teil***, Bd. VIII, 1908, p XIX 91, fig 116, Boyer, *Syn N Am Diat* 1926, p 108, Lebour, ***Plank*** *Diat N Seas*, 1930, p 156, fig 120, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 737, fig 426

Chains spirally curved No distinct end cell Apical axis of cell measuring 9–21 μ Cells in broad girdle view oblong, setæ starting from the corners. Aperture somewhat broadly elliptical Setæ all directed toward one side of the chain Chromatophore a single plate with pyrenoid Resting spores formed one in each cell, wall smooth

Distribution —All parts of North Sea, Norwegian Sea, Skaggerak, Baltic Sea, English Channel, Belgium coast, North Atlantic, European and American, Mediterranean Sea and California

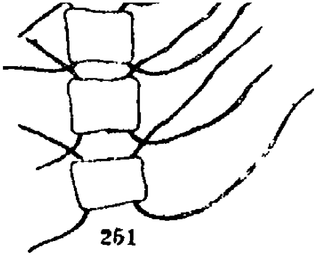
Socialia

77 *Chætoceros socialis* Lauder

(Figs 251 and 256)

Lauder, *Diat Hong Kong*, 1864 *b*, p 77, Pl VIII, fig. 1, De Toni, *Syll Alg*, Vol II, 1891–94, p 995, Gran, *Nord Plank.*, *Bot Teil*, Bd VIII, 1908, p XIX 96, fig. 123, Boyer, *Syn N Am Diat*, 1926, fig 110, Lebour, ***Plank Diat N Seas***, 1930, p 166, fig 128, Hustedt, Rabenhorst's ***Kryptogamen-Fl***, Bd VII, Teil 1, 1930 *b*, p 751, fig 435

Cells forming curved chains, apical axis measuring 5–14 μ, number of chains occur together in colonies. Setæ very thin. The setæ on one side



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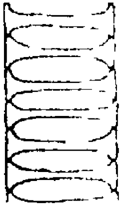

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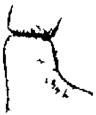

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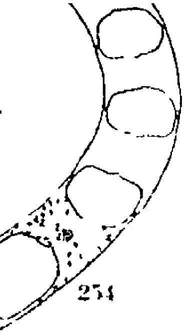

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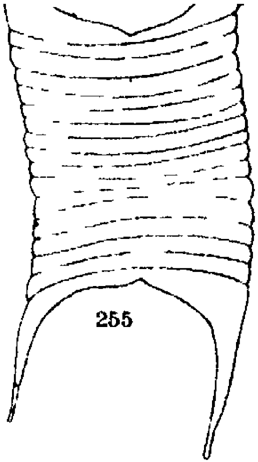

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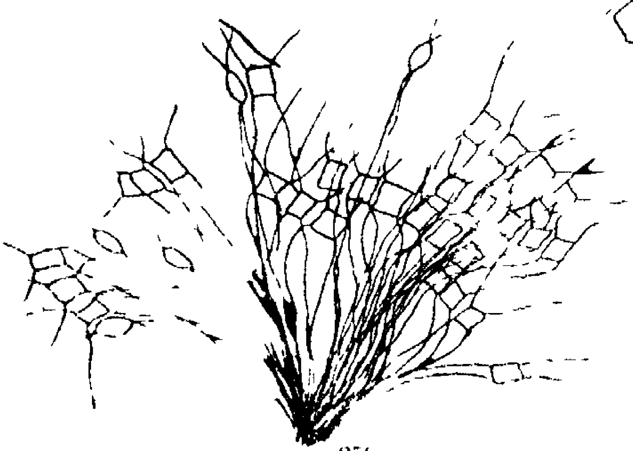

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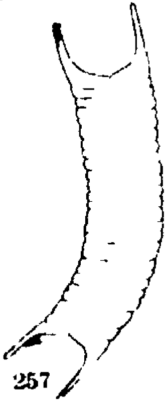

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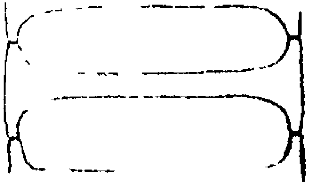

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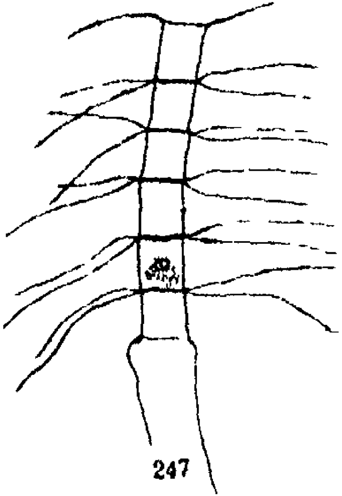
TEXT-FIGS 247–258.—Fig 247 *Ch Wighami* Brightwell ×460 Fig 248 *Eucampia zoodiacus* Ehrenberg. ×328 Fig 249 *Climacodium Frauenfeldianum* Grunow ×130.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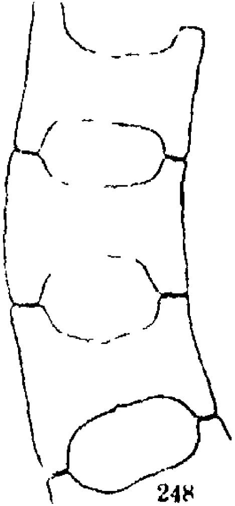
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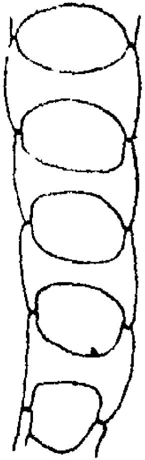
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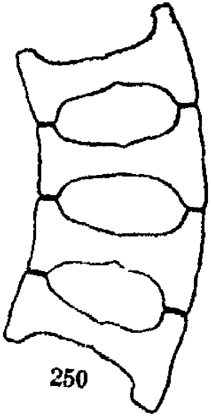
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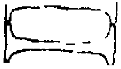


Fig. 250. ***Eucampia zoodiacus*** **Ehrenberg.** ×328 Fig 251 ***Chætoceros socialis*** **Lauder** **A chain** ×710 **Fig. 252** ***Climacodium*** *Frauenfeldianum* Grunow ×80 **Fig 253** ***Eucampia zoodiacus*** Ehrenberg Structure × 710 Figs 254 255 *E cornuta* (Cleve) Grunow, a chain, one cell showing contents × 220 255, × 710 Fig 256 *Chætoceros socialis* Lauder A colony. × 150 Fig. 257 *Eucampia cornuta* (Cleve) Grunow × 460 Fig 258 *Climacodium Frauenfeldianum* Grunow ×220

of the chain almost all prolonged very much and sometimes attached to some foreign body Apertures large, somewhat rectangular

Distribution—Hong Kong, Arctic Seas, Davis Strait, Danish Seas, Skaggerak, Baltic, North Sea, Belgian coast, English Channel; North Atlantic, European and American

Family BIDDULPHIEÆ

Sub-family EUCAMPINEÆ

XXIV Genus *Eucampia* Ehrenberg

78 *Eucampia zoodiacus* Ehrenberg

(Figs 248, 250 and 253)

Pritchard, *Hist Infusoria,* 1861, p 937, Pl II, fig 43, Rabenhorst, *Fl. Eu Alg*, 1864, p 324, fig 93, De Toni, *Syll Alg*, Vol II, 1891–94, p 983, Van Heurck, *Traité des Diatomées*, 1899, p 461, fig 191, Pl XIX, fig 628; Gran, *Nord Plank., Bot Teil,* Bd VIII, 1908, p XIX 98, fig 126; Boyer, *Syn. N. Am Diat*, 1927, p. 116, Lebour, *Plank. Diat N Seas,* 1930, p. 187, fig. 147, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 772, fig. 451; Allen and Cupp, *Plank. Diat Java Sea,* 1935, p 143, fig 74.

Eucampia Britannica W. Smith, *Syn Brit Diat*, Vol. II, 1856, p 25, Pl. LXXI, fig. 378

Eucampia groenlandica Cleve, *Diat Baffins Bay,* etc., 1896, p. 10, Pl. II, fig 10

Cells flat, united into spirally twisted chains by blunt processes. Apical axis 44–60 μ in length. Valves concave in the middle part so that between neighbouring cells a large space occurs. Intercalary bands difficult to make out. Valve punctate, punctæ 15 rows in 10 μ.

Distribution.—All parts of North Sea, Baltic, Skaggerak, English Channel, Mediterranean, North Atlantic, European and American, California; Miocene deposits of Richmond

79 *Eucampia cornuta* (Cleve) Grunow

(Figs. 254, 255 and 257)

Van Heurck, ***Traité des Diatomées***, 1899, p 461, fig 192; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 774, fig 452; Allen and Cupp, ***Plank Diat*** *Java Sea*, 1935, p 143, fig 75

Moellaria cornuta Cleve, *Diat Sea of Java*, 1873 *a*, p 7, Pl I, fig. 6.

Similar to former in habit Apical axis 18–42 μ in length Intercalary bands prominent Processes thinner and longer. Apertures wider than in the former Structure on valve very difficult to see.

Distribution.—Usually in the warmer seas, Java In the European region only in the warmer sub-tropical parts of the Atlantic Ocean

XXV Genus *Climacodium* Grunow

80 *Climacodium Frauenfeldianum* Grunow

(Figs 249 252 and 258)

De Toni, *Syll Alg*, Vol II, 1891–94, p 986, Van Heurck, ***Traité des Diatomées***, 1899, p 462, fig 193, Gran, *Nord Plank*. ***Bot Teil***, Bd VIII, 1908, p XIX 100, fig 129, Lebour, *Plank Diat N Seas*, 1930, p 189, fig 149 *a*, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd Teil I, 1930 *b*, p 776, fig 453, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 144, fig 76

Cells even, flat, forming very long ribbon-shaped chains, in girdle view with small linear middle part, at the poles of the apical axis with more or less slender processes Intercalary bands absent, pervalvar axis, therefore, short Apertures large, wider than the cells Membrane structure not visible. Apical axis 106–160 μ in length

Distribution—Particularly in the warmer seas, Mediterranean, Indian Ocean, Red Sea

XXVI Genus *Streptotheca* Shrubsole

81 *Streptotheca indica* Karsten

(Figs 259, 260)

Karsten, ***Valdivian Expedn***, 1907, p. 395, Taf XLVI, fig 8, *a*, *b* Allen and Cupp, ***Plank Diat Java Sea***, 1935, p 144, fig 77

Cells square to rectangular, membranaceous, forming long chains which are at times twisted on its own axis Chromatophores numerous, disc-shaped

Distribution.—Indian Ocean, Java Sea

Sub-family TRICERATINEÆ

XXVII. Genus *Bellarochea* Van Heurck

82 *Bellarochea malleus* (Brightwell) Van Heurck

(Figs 261, 262)

Van Heurck, *Traité des Diatomées*, 1899, p 464, fig 195; Gran, *Nord Plank*, *Bot Teil*, Bd. VIII, 1908, p XIX 111, fig 148; Lebour, *Plank Diat N Seas*, 1930, p 182, fig 142, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 782, fig 456

Triceratium malleus Brightwell, *Further Observations*, etc, 1858 *b*, p. 154, Pl VIII, figs. 6, 7.

Cells flat, forming ribbon-like chains, weakly silicified Apical axis 50–78 μ in length Valve with a rudimentary central knob and punctate in the margin. Apertures slit-like, closed in the middle by rounded valves Chromatophores numerous, disc-shaped

Distribution —Neritic in the coastal region of south, North Sea, Atlantic coast of western Europe and America, Indian Ocean.

XXVIII Genus *Ditylum* Bailey

83 *Ditylum Brightwellii* (West) Grunow

(Figs 263 and 264)

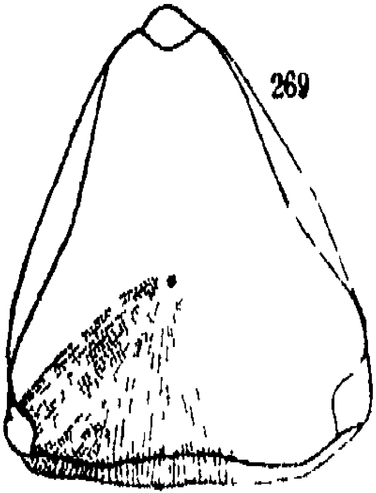
De Toni, *Syll Alg*, Vol II, 1891-94, p 1017, Van Heurck, *Traité des Diatomées*, 1899, p 424, fig 141, Pl XVII, fig 606, Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX, 112, fig 150, Lebour, *Plank Diat N Seas*, 1930, p 186, fig 146; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 784, fig 457

Triceratium undulatum Brightwell, *Further Observ*, 1858 *b*, p 154, Pl VIII, e p ;

Triceratium Brightwellii West, *Remarks Diat.*, 1860, p 149, Pl. VII, fig. 6.

Cells prism-shaped, with strongly rounded ends and three-cornered valvar plane. Valve margin wavy Sides of valve measuring 46–132 μ. Membrane finely punctate A circle of short spines on the valve surface and a siliceous hollow spine at the centre of the valve.

Distribution —Coasts of England and Scotland, North Sea, Holland, Belgium, Germany, Norway, Sweden and Denmark; North Atlantic, European and American.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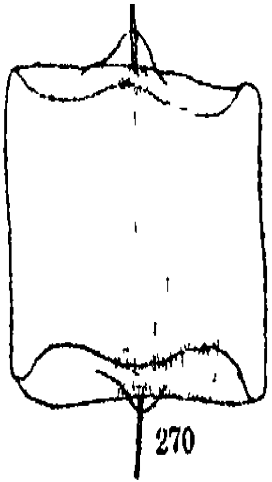
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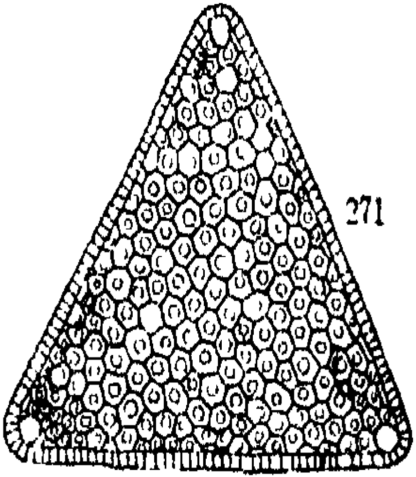
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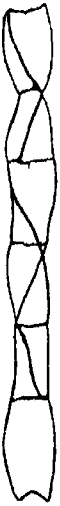
TEXT-FIGS, 259–271 —Figs. 259–260. *Streptotheca indica* Karsten. Fig. 259, × 80, 260 ×328 Figs 261-262 *Bellerochea malleus* (Brightwell) Van Heurck Fig 261, shows the spin and structure ×710, 262, a chain, ×328 Figs 263–264 *Ditylum Brightwellii* (West) Grunow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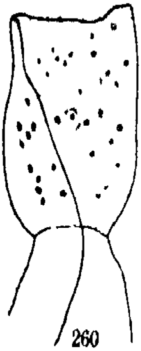
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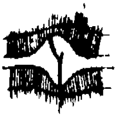
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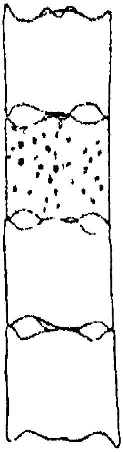
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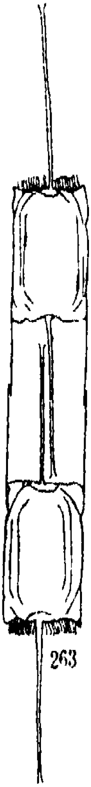
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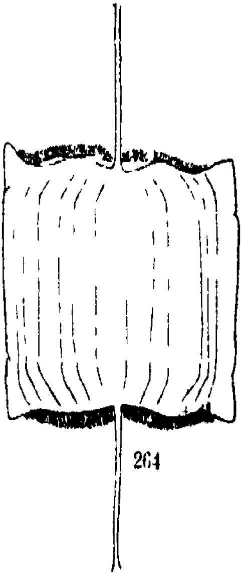
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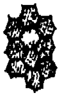
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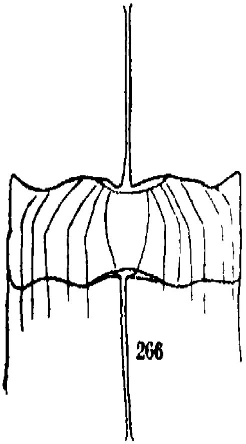
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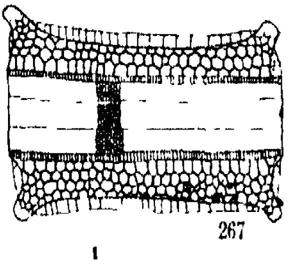
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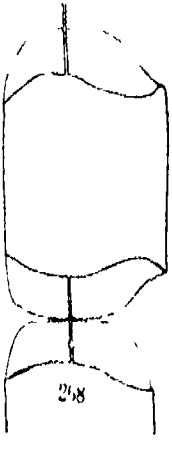
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Fig. 263, two daughter cells, ×325; 264, ×328. Fig 265 *Triceratium favus* Ehrenberg. Structure on the valve × 460 Fig. 266 *Ditylum Sol* Grunow × 325 Fig 267 *Triceratium favus* Ehrenberg ×460 Figs 268–270 *Lithodesmium undulatum* Ehrenberg Fig 268 and 270, ×710, 269, valve view showing sculpturing, ×930 Fig 271 *Triceratium favus* Ehrenberg ×460

84 *Ditylum Sol* Grunow

(Fig. 266)

De Toni, *Syll Alg*, Vol II, 1891–94, p 1018, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 787, fig 460, Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 145, fig 79

Cells very large, with three cornered valves possessing a central, straight, hollow spine No circle of small spines on valve Valve margin wavy, giving the appearance of many longitudinal lines in girdle view. Membrane finely punctate Sides of the valves measuring 110–148 μ

Distribution.—Warm water form In the Atlantic Ocean up to 10° N. In Europe only in the eastern part of Mediterranean, Gulf of Java and China Sea.

XXIX Genus *Lithodesmium* Ehrenberg

85 *Lithodesmium undulatum* Ehrenberg

(Figs 268–270)

De Toni, *Syll Alg*, Vol II, 1891–94, p 985, Gran, *Nord. Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 112, fig 149, Lebour, *Plank. Diat N Seas*, 1930, p 185, fig 145; Hustedt, Rabenhorst's *Krvptogamen-Fl*. Bd VII, Teil 1, 1930 *b*, p. 789, fig 461

Triceratium undulatum Brightwell, *Further Observ*, 1858 *b*, p. 154, Pl. VIII, e.p.;

Ditylum intricatum Grunow, Van Heurck, *Traité des Diatomées*, 1899, p. 424, Pl XVII, fig. 607.

Lithodesmium Victoriæ Karsten, *Valdivian Expedn*. 1907, p 171, Taf. XXVIII, fig. 6.

Cells forming long chains. Valvar plane triangular, corners rounded Valve with a small spine at the centre. Sides of valve measuring 38–49 μ Membrane punctate, punctæ 12 rows in 10 μ.

Distribution.—Coasts of England, North Sea, Holland, Belgium, Germany and California.

XXX Genus *Triceratium* Ehrenberg

86 *Triceratium favus* Ehrenberg

(Figs 265, 267 and 271, Pl I, fig 5)

W Smith, *Syn Brit Diat*, Vol I, 1853, p 26 Pl V, fig 44, Pl XXX, fig 44, De Toni, *Syll Alg*, Vol II, 1891–94, p 917, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 798, figs 462, 463

Triceratium muricatum Brightwell, *On the Genus Triceratium,* 1853, p 249, Pl IV, fig 5

Triceratium scitulum Brightwell, *Further Observ*, 1858 *b*, Pl IV, fig 9

Triceratium fimbriatum Wallich, *On Triceratium*, etc, 1858, p 247, Pl XII, figs 4–9

Triceratium favus var *spinigera* Cleve, *Diat Sea of Java*, 1873 *a*, p 6, Pl I, fig 3

Triceratium favus var *lateareolata* Castracane, *Diat Chall*, 1886, p 109, Pl IX, fig 3

Triceratium sarcophagus Castracane, *ibid*, Pl VI, fig 3

Triceratium ferox Castracane, *ibid*, Pl VI, fig 4

Biddulphia favus Van Heurck, *Traité des Diatomées*, 1899, p 475, fig 204 Pl XXI, fig 643, Boyer, *Biddulphioid Forms* 1900, p 706, Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 109, fig 147, Boyer, *Syn N Am Diat*, 1926, fig 133, Lebour, *Plank Diat N Sea*, 1930, p 180, fig 140

Cells box-like with three-cornered valvar plane and short pervalvar axis Sides of valve slightly convex, the corners rounded, side measuring 96–166 μ At the corners blunt processes present Cell-membrane strongly sculptured, areolate Areolæ in regular rows, almost of the same size measuring 2–3 μ in diameter Primary membrane punctate, punctæ 12 in 10 μ Chamber openings clear Girdle band areolate-punctate, punctæ 6–8 rows in

Distribution —Littoral in all the European seas Atlantic coast; Gulf of Mexico and Java

87 *Triceratium Robertsianum* Greville

(Figs 272 and 273)

Greville, *Descrip New and Rare Diat*, 1863 *c*, p 231, Pl IX, fig 9; De Toni, *Syll Alg*, Vol. II, 1891–94, p 919, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 803, fig 466

Biddulphia Robertsiana Boyer, ***Biddulphioid Forms,*** 1900, p 707; Boyer, *Syn. N Am Diat*, 1927, p 134

Cell built in the same plan as *T favus* Valves three-sided, sides more convex, measuring 142 μ Valve corners with hollow cylindrical process Cell membrane strongly sculptured, areolate Areolæ 10–25 in 100 μ

Distribution —Littoral form in the coast of tropical and sub-tropical seas; in Europe only in the Mediterranean

88 *Triceratium dubium* Brightwell

(Figs 274–276 and 278)

Brightwell, *On Rarer and Undescribed Diat* 1859, p 180, Pl IX, fig 12, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII Teil 1, 1930 *b* p 806 fig 469

Triceratium bicorne Cleve, *Diat West Ind Arch*, 1878, p 17 Pl V, fig 30

Biddulphia bicornis Cleve, *ibid*

Amphitetras bicornis De Toni, *Syll Alg*, Vol II, 1891–94, p 902

Biddulphia dubia (Brightwell) Cleve, Boyer, *Biddulphioid Forms*, 1900, p. 707; Boyer, *Syn N Am Diat*, 1926 p 128, Allen and Cupp, *Plank, Diat Java Sea*, 1935, p 148, fig 84

Valves rhombic-lanceolate In side-view two angles each with a stout horn-like process and the other two angles with short blunt processes Valve three, four, five-sided or irregularly shaped Valve surface strongly sculptured, areolated irregularly, areolæ 6 in 10 μ Valve margin striated Girdle band areolate, areolæ 12 in 10 μ arranged in rows Apical axis 21–34 μ.

Distribution —In the coast of warmer seas, in Europe only in the Balearic Sea, Mauritius, Atlantic and Pacific coasts of America and Java

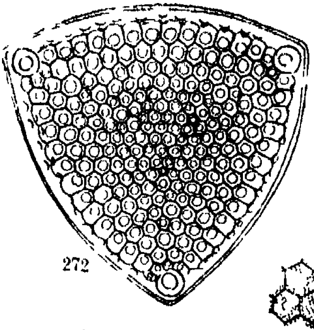
89 *Triceratium reticulum* Ehrenberg

(Figs 279 and 280)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII Teil 1, 1930 *b* p 823, figs. 485 and 486

Triceratium sculptum Shadbolt, *New Forms Diat*, 1854 *a*, p 15, Pl I, fig. 4.

Triceratium punctatum Brightwell, *Further Observ Genus Triceratium*, 1856 *b*, p. 275, Pl IX, fig 18, Pritchard, *Hist Infusoria*, 1861, p 856, Pl VI, fig 20, De Toni, *Syll Alg*, Vol II, 1891–94, p. 944.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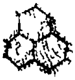
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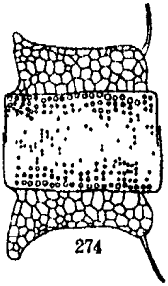
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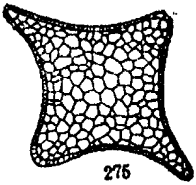
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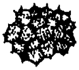
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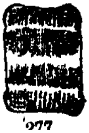
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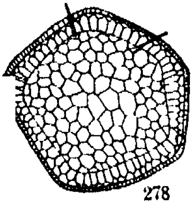
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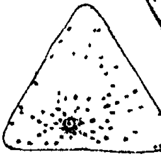
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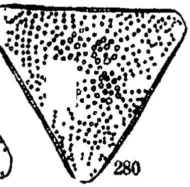
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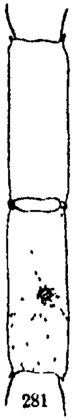
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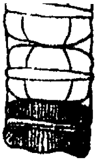
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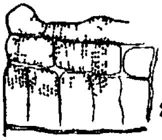
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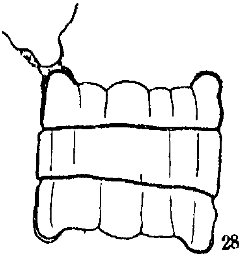
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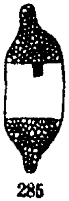
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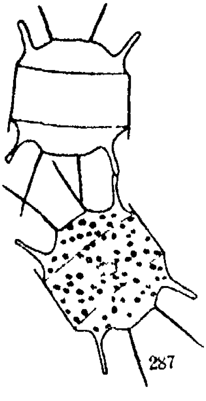
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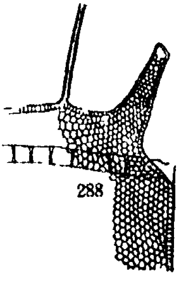
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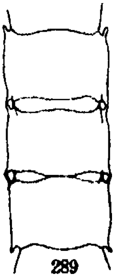
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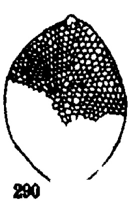
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TEXT-FIGS. 272–290 Figs 272–273 *Triceratium Robertsianum* Greville Fig. 272, ×325, 273, sculpturing on the valve, × 710. Figs. 274–276. *T. dubium* Brightwell × 930, 276 sculpturing on the valve Fig. 277 *T alternans* Bailey ×710 Fig 278 *T dubium* Brightwell, abnormal valve, × 930 Figs 279–280 *T reticulatum* Ehrenberg Fig 279, cell with contents, ×710; 280 × 930 Fig 281 *Biddulphia sinensis* Greville × 83 Fig 282 *Triceratium alternans* Bailey A chain ×710 Figs 283–284 *Biddulphia pulchella* Gray ×328 Fig. 285. *B rhombus* (Ehrenberg) W Smith Narrow girdle view ×930 Figs 286–287 *B mobiliensis* Bailey Fig 286, sculpturing, ×930, 287, ×328 Fig 288 *B heteroceros* Grunow Sculpturing ×930 Fig 289 *B sinensis* Greville ×83 Fig 290 *B rhombus* (Ehrenberg) W Smith Valve view × 930

Biddulphia sculpta (Shadbolt) Van Heurck, *Traité des Diatomées*, 1899, p. 476, Pl XXI, fig 645

Biddulphia reticulum (Ehrenberg) Boyer, *Biddulphioid forms*, 1900, p 724; Boyer, *Syn N. Am Diat*, 1926, p. 138, Gran, *Nord Plank*, *Bot Teil*, Bd. VIII, 1908, p XIX 110, fig. 146

Cells with triangular valvar plane sides measuring 28–125μ, Corners rounded. Cell-wall areolate, areolæ rounded, 7–12 in 10μ scattered and of different sizes, frequently groups of areolæ separated by a hyaline ring

Distribution —Littoral region of warmer seas, very frequent, In Europe from the Mediterranean to the Scandinavian coast

90. *Triceratium alternans* Bailey

(Figs 277 and 282)

W. Smith, *Syn. Brit. Diat*, Vol I, 1853, p 26, Pl V, figs 30 and 45; Gran, *Nord. Plank.*, *Bot Teil*, Bd VIII, 1908, p XIX 110, fig 145, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 825, fig. 488

Biddulphia alternans Van Heurck, De Toni, *Syll Alg*, Vol II, 1891–94, p. 941; Van Heurck, *Traité des Diatomées*, 1899, p 475, Pl XXI, fig 644; Boyer, *Biddulphioid forms*, 1900, p 719, Boyer, *Syn N Am Diat*, 1926, p. 137.

Triceratium variable Brightwell, *Further Observ. Genus Triceratium*, 1856 *b*, p. 275, Pl. XVII, fig. 19.

Cells box-shaped with three-sided valvar plane, sides measuring 16–19μ. Corners rounded. Membrane areolate, areolæ somewhat rounded on the valve, 9 in 10μ, on the girdle 12 in 10μ, becoming smaller towards the centre of the girdle.

Distribution —In the entire European coastal region, not rare. In the plankton as chains formed by mucilage secretions.

Sub-family BIDDULPHINEÆ

XXXI Genus *Biddulphia* Gray

91 *Biddulphia pulchella* Gray

(Figs 283 and 284)

W Smith, *Syn Brit Diat*, Vol II, 1856, Pl XLIV, fig 321; De Toni, *Syll Alg*, Vol II, 1891-94, p 870, Van Heurck, *Traité des Diatomées*, 1899, p 470, Pl XX, fig 630, Lebour, *Plank Diat N Seas*, 1930, p 172, Pl III fig 3, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 832, fig 490

Biddulphia pulchella var *major* Castracane, *Diat Chall*, 1876, p 102, Pl XXIII, fig 6

Biddulphia biddulphiana (Smith) Boyer, *Biddulphioid forms*, 1900, p 694; Gran, *Nord Plank Bot Teil*, Bd VII, 1908, p XIX 104, fig 135, Boyer, *Syn N Am Diat*, 1926, p 121

Valves elliptical with swollen margins, strongly sculptured with a few ribs inside. Two blunt, rounded processes at the corners; structure, areolations on both valve and girdle, on girdle arranged in rows more or less, 4½ in 10 μ Apical axis 92 μ in length Cells forming long or short chains by attachment with mucilage pads at blunt end of their processes

Distribution--One of the commonest form in the European coastal region, particularly frequent in the temperate parts, becoming rare towards the north Found in long chains along with other types. Also in the plankton of Atlantic and Pacific coasts

92 *Biddulphia sinensis* Greville

(Figs 281 and 289)

Greville, *Descrip New and Rare Diat*, 1866, ser xix, p 81, Pl. IX, fig 16; Gran, *Nord Plank*. *Bot Teil*, Bd VIII, 1908, p XIX, 107, fig 139, Lebour, *Plank Diat N Seas*, 1930, p 176, fig 136, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 837, fig 493; Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 146, fig 81.

Denticella? sinensis De Toni, *Syll Alg*, Vol. II, 1891-94, p. 884

Cells large, weakly silicified, cylindrical, elliptical—lanceolate in valve view, pervalvar axis elongated Apical axis measuring 120-196 μ. Girdle band not clearly demarcated Two thin horns at the corners of the valve and near each other a long thin spine Membrane very finely areolated, areolæ in rows on the girdle.

Distribution.—All parts of the North Sea, Skaggerak, Cattegat, Irish Sea, English Channel, Indian seas, Red Sea, Hong Kong, Java, Gulf of Siam.

93. *Biddulphia mobiliensis* Bailey

(Figs. 286, 287, 291–296 and 299, Pl II, figs 1 and 2)

De Toni, *Syll Alg*, Vol II, 1891–94, p 382, Boyer, *Biddulphioid forms*, 1900, p 698; Gran, *Nord Plank Bot Teil*, Bd VIII, 1908, p XIX 106, fig 138 *d*; Boyer, *Syn N Am Diat*, 1926, p 122, Lebour, *Plank Diat. N Seas*, 1930, p. 174, fig 134, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p. 840, fig. 495, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 146, fig 80

Biddulphia Baileyi W. Smith, *Syn Brit Diat*, Vol II, 1856, p 50, Pl. XLV, fig 322 *c*

Cells elliptical-lanceolate in valve view, single, or forming short chains attached by their horns Valve and girdle zone not clearly demarcated Thin walled Valve horns slender and directed outwards Two long straight spines on each valve placed equally apart from the horns Valve flat between the spines Both valve and girdle areolated, areolæ in regular rows 12 in 10 μ on the valve, 18 in 10 μ on the girdle Apical axis of cells 26–79 μ

Auxospores were observed

Distribution—Norwegian seas, all parts of the North Sea, English Channel, North Atlantic (European and American), Mediterranean, Pacific coast of America

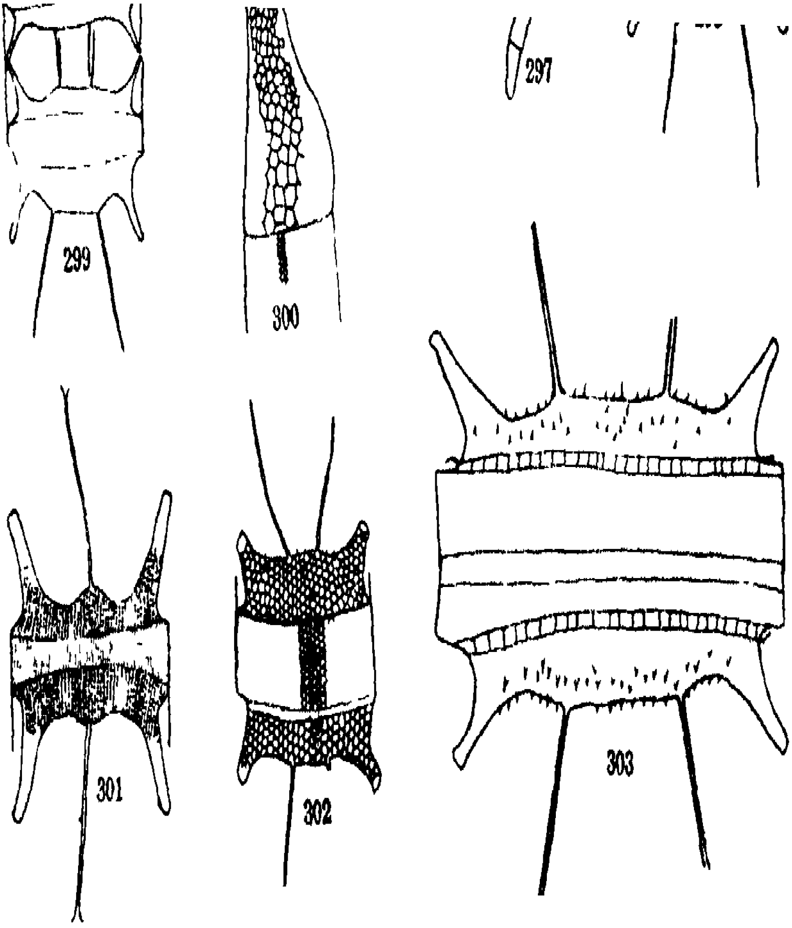
94 *Biddulphia heteroceros* Grunow

(Figs 288, 298 and 303)

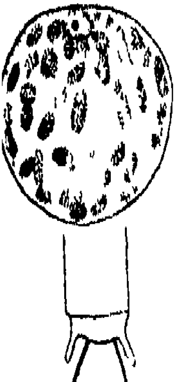
Allen and Cupp, *Plank. Diat Java Sea*, 1935, p 147, fig 82.

Cells box-shaped without a sharp constriction between valve and girdle zone in girdle view Horns from each pole of apical axis well developed, directed slightly away from pervalvar axis Two strong spines on each valve a short distance from the horns Valve between spines slightly higher, that between spines and horns somewhat flat Valve surface studded with numerous tiny spines On lower margin of valve mantle, a hyaline collar supported by ribs present Areolation almost of the same size on valve and girdle, in regular rows, 9 in 10 μ

Distribution—Java Sea



TEXT-FIGS 291–303.—Figs 291–296 *Biddulphia mobiliensis* Bailey Stages in auxospore-formation. ×328 Fig. 295, cell inside perizonium, 296, stained auxospore. Note large nucleus and a degenerating one near it Fig. 297, *Isthmia enervis* Ehrenberg. A colony. ×53,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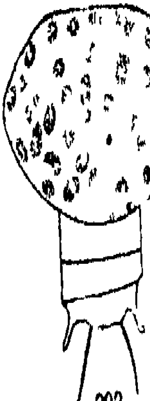
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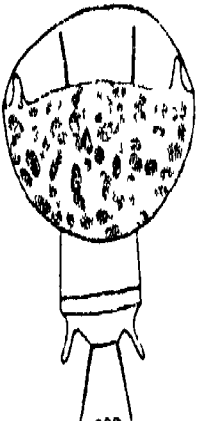
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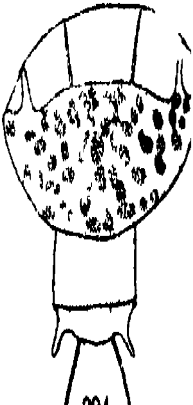
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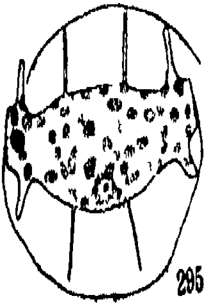
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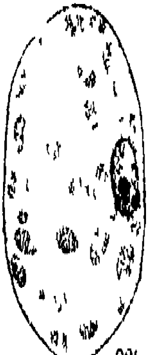
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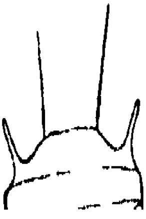

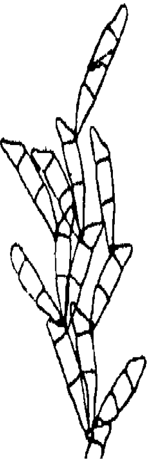

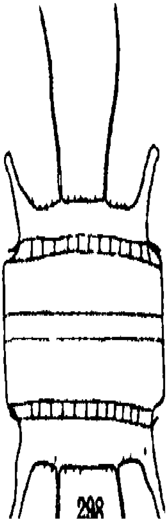
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Fig 298 *Biddulphia heteroceros* Grunow × 460 Fig 299 *B mobiliensis* Bailey × 328 Fig. 300 *Isthmia enervis* Ehrenberg Sculpturing × 328 Fig 301 *Biddulphia longicruris* Greville × 930 Fig 302 *B rhombus* (Ehrenberg) W Smith × 930 Fig 303 *B heteroceros* Grunow 460

95 *Biddulphia rhombus* (Ehrenberg) W Smith

(Figs 285, 290 and 302)

W Smith, *Syn Brit Diat*, Vol II, 1856, p 49, Pl XLV, fig 320, Pl LXI, fig. 320, De Toni, *Syll Alg*, Vol II, 1891–94, p 882, Van Heurck, *Traité des Diatomées,* 1899 p 472, Pl XX, fig 634, Boyer, *Biddulphioid forms*, 1900, p 704; Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 108, fig. 141, Boyer, *Syn N Am Diat*, 1926, p 127, Lebour, *Plank Diat N Seas*, 1930, p. 178, fig 138, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*, p 842, fig 496, 497

Cells strongly silicified, and strongly sculptured Valves and girdle zone differentiated. Horns stout Valves with two long spines Membrane areolated, areolæ 9 in 10 μ on valve, 18 in 10 μ on the girdle Apical axis 26–27 μ in length

Distribution —Coasts of England, North Sea, Holland, Belgium, Germany, Sweden, Denmark, North Atlantic, Atlantic and Pacific coasts of America, Mauritius

96 *Biddulphia longicruris* Greville

(Fig 301)

Greville, *Diat Cal Guano*, 1859 *b*, p 163, Pl VIII, fig 10

Cells somewhat resembling *Biddulphia aurita*, well silicified, box-shaped, valvar plane elliptic to lanceolate, apical axis 20–42 μ in length Valve at the poles of the apical axis drawn out into well developed horns. Cell wall areolate, areolæ 12 in 10 μ on the valve, about 18 in 10 μ on the girdle; radially arranged on the valve Spine one on each valve, well developed.

Distribution —Californian guano

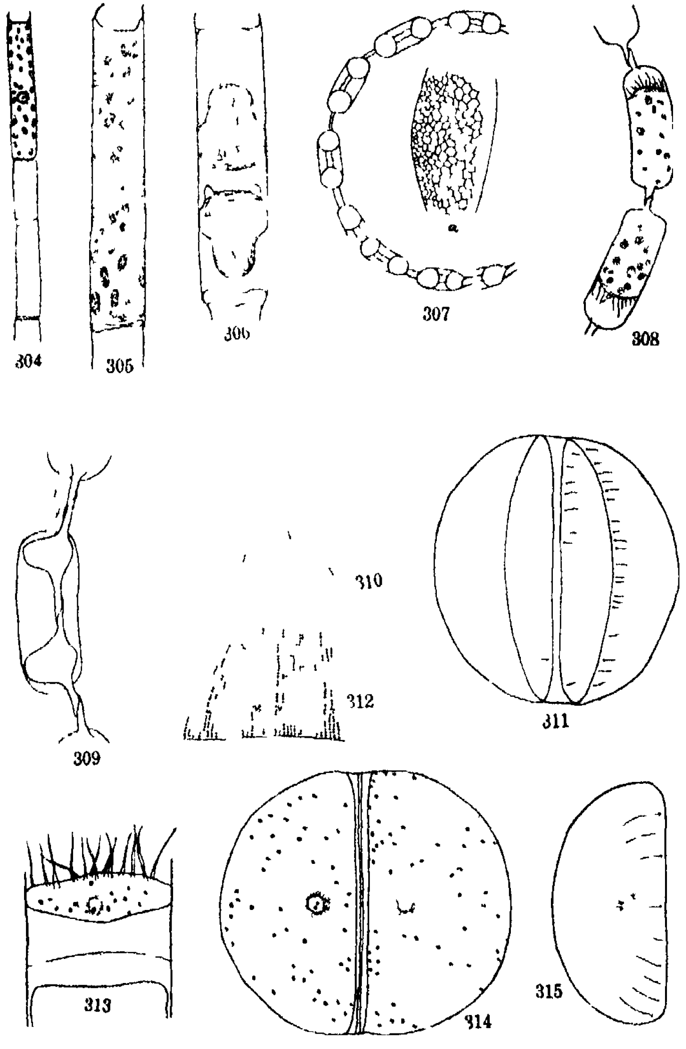
Family ISTHEMINEÆ

XXXII Genus *Isthmia* Agardh

97 *Isthmia enervis* Ehrenberg

(Figs 297 and 300)

W Smith, *Syn Brit Diat*, Vol II, 1856, p. 52, Pl XLVIII Pritchard, *Hist Infusoria*, 1861, p 851, Pl X, fig 183, Van Heurck, *Traité des Diatomées*, 1899, p. 451, fig. 175 *a*, Pl XIX, fig. 625; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd. VII, Teil 1, 1930 *b*, p. 866, fig. 516.



Text-Figs 304–315 —Figs 304–306 *Cerataulina Bergonii* Peragallo, × 328 Fig 306, resting spore Figs 307–309 *Hemiaulus sinensis* Greville Fig 307, a chain × 150, 307*a*, sculpturing, × 930, 308, 309, narrow girdle view, × 460, 308, resting-spore formation Figs. 310–312, ***Hemiaulus Hardmannianus*** (Greville) Mann Fig 310, × 710, 311, × 150, 312, × 710 Fig 313 ***Hemiaulus sinensis*** Greville, resting spore × 460 Figs 314–315 ***Hemidiscus Hardmannianus*** (Greville) Mann Fig 314, 315, × 150.

Isthmiella enervis Cleve, *Diat Arctic Sea*, 1873 *b*, p 10.

Isthmiella enervis (Ehrenberg) Cleve, De Toni, *Syll. Alg*, Vol II, 1891–94, p 834

Isthmia obliquata (J E Smith) Boyer, *Biddulphioid forms*, 1900, p 689; Boyer, *Syn N. Am Diat*, 1926, p 140

Cells forming colonies, frustules elongated Valves without costæ Girdle well developed Cells showing two poles, one, a foot pole by which attachment is effected, and the other less long and somewhat more rounded Valve areolated, areolæ 2½ in 10 μ Girdle also areolated, areolæ in rows, 7 in 10 μ

Distribution.—In all oceanic coasts from Arctic Seas to the Tropics

Family HEMIAULINEÆ

XXXIII Genus *Cerataulina* Peragallo

98 *Cerataulina Bergonii* Peragallo

(Figs 304–306)

Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 101, fig 132, Boyer, *Syn N Am Diat*, 1927, p 559, Lebour, *Plank Diat N Seas*, 1930, p 185, fig 144, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil, 1, 1930 *b*, p 869, fig 517 Allen and Cupp, *Plank Diat Java Seas*, 1935, p 149, fig 86

Cells cylindrical, elongated along pervalvar axis, forming long chains Intercalary bands difficult to see At the margin of the valve two short cylindrical processes with hair-like spine on them Apertures small Cell-wall weakly siliceous Structure on valve not clear. Apical axis measuring 11–26 μ

Resting spores were observed in this form But the shape of the spore is very different from that figured by Hustedt (1930 *b*, p 869, fig 517), probably the spores observed here were not mature

Distribution –In the warmer seas, in Europe not rare. In the Mediterranean very common, neritic

XXXIV Genus *Hemiaulus* Ehrenberg

99 *Hemiaulus sinensis* Greville

(Figs 307–309 and 313)

Greville, *Descrip New Genera and Sp Diat*, 1865 *b*, p 5, Pl V, fig. 9; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 1, 1930 *b*,

p. 875, fig. 519; Allen and Cupp, *Plank. Diat Java Sea*, 1935, p. 150, fig 88

Hemiaulus Heibergii Cleve, *Diat Sea of Java*, 1873 *a*, p. 6, Pl. I, fig. 4; De Toni, *Syll. Alg.*, Vol. II, 1891-94, p 837.

Cells flat with broadly elliptical valvar plane, forming long chains by attachment with the processes of adjoining cells Apical axis measuring 23-38 μ. Cell wall strongly silicified, areolated, areolæ in somewhat radial rows; at the centre of the valve about 6 in 10 μ, near margin 9 in 10 μ.

Distribution--Neritic in the coastal region of warmer and southern seas; in Europe only in the Mediterranean

Family EUODIEÆ

XXXV Genus *Hemidiscus* Wallich

100 *Hemidiscus Hardmannianus* (Greville) Mann

(Figs. 310-312 and 314-315)

Allen and Cupp, *Plank. Diat Java Sea*, 1935, p. 152, fig. 91.

Palmeria Hardmanniana Greville, *Descrip. New and Rare Diat.*, 1865 *a*, p. 1, Pl. 5, fig 1-4.

Valves semicircular, ventral margin straight. Ends obtuse Central area somewhat large and hyaline. Areolation fine, radiating from the centre, about 12 in 10 μ. Spinulæ around the margin, with hyaline ribs arising from them and running to the centre.

Distribution.—Java Sea

PART II

Bacillariophyta (Diatomeæ)

Order: PENNALES

Sub-order ARAPHIDINEÆ

Family. Fragilarioideæ

Sub-family: Tabellarieæ

Tabellarineæ

XXXVI Genus *Rhabdonema* Kutzing

101 *Rhabdonema mirificum* W Smith

(Figs 316, 318 and 319)

W Smith, *Syn Brit. Diat*, Vol II, 1856, p 35, Pl XXXVIII, figs. 305 *b*, 305 *a′*, *b′*; Walker-Annott, *On Rhabdonema*, 1858 *a*, p 92; Brightwell, *Rarer or undescrib Diat*, 1859, p 180, Pl IX, fig 11, Pritchard, *Hist Infusoria*, 1861, p 805, Pl VIII, fig 12

Climacosira mirifica (W. Smith) Grunow, De Toni, *Syll Alg*, Vol. II, 1891-94, p 765; Van Heurck, *Traité des Diatomées*, 1899, p 361, fig 112

Rhabdonema punctatum (Harv and Bailey) Stoddar, Boyer, *Syn N. Am Diat*, 1926, p. 150

Cells in girdle view ribbon-shaped with hyaline rounded corners forming more or less long bands Intercalary bands numerous Valves linear, 81–117 μ long, transversely striate, striæ 12-15 μ Valve view was not observed

Distribution—Ceylon, Mauritius, Red Sea; Tahiti, Honduras, Pacific Ocean; in the fossil of "Nankoori".

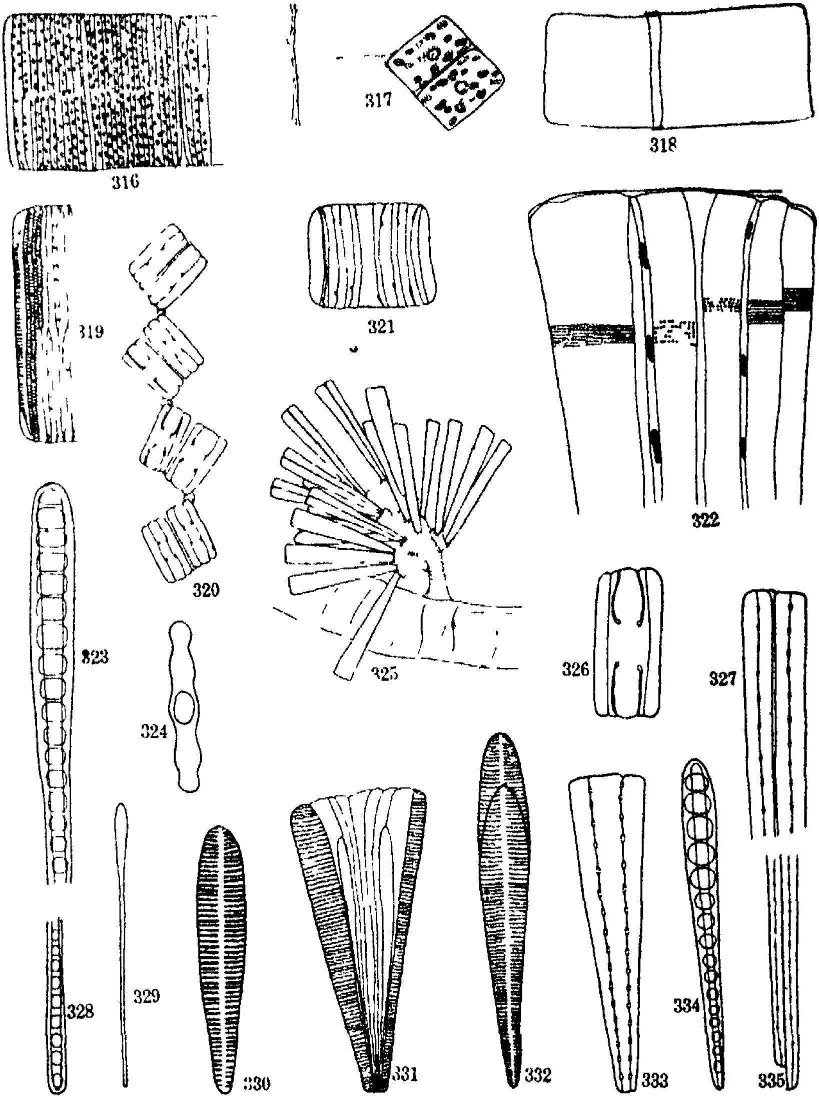
XXXVII Genus *Striatella* Agardh

102. *Striatella delicatula* (Kützing) Grunow

(Figs 317 and 321)

Pritchard, *Hist. Infusoria*, 1861, p 804, Pl XIV, fig. 42; Van Heurck, *Traité des Diatomées*, 1899, p 363, Pl XII, fig. 483; Boyer, *Syn N. Am. Diat*, 1926, p. 161; Hustedt, Rabenhorst's *Kryptogamen-Fl.*, Bd VII, Teil 2, 1931-32, p. 34, fig. 51.

Frustules rectangular, angles rounded, divided into partitions by septa which alternate on each side Valves 14–18 μ long Striæ not clearly visible.



TEXT-FIGS 316–335 —Fig 316 *Rhabdonema mirificum* W Smith ×220 Fig 317 *tella delicatula* (Kützing) Grunow × 428 Figs 318–319 *Rhabdonema mirificum* W Smith Fig. 318, ×220, 319, sculpturing, × 460. Fig 320. *Grammatophora undulata* Ehrenberg × 325.

Fig. 321 *Striatella delicatula* (Kütz) Grunow ×930 **Fig 322** *Climacosphenia moniligera* Ehrenberg, sculpturing × 930 **Fig 323** *Cl elongata* Bailey, valve view free end ×220. **Fig 324** *Grammatophora undulata* Ehrenberg, valve view × 428 **Fig 325** *Climacosphenia moniligera* Ehrenberg, a colony × 53 **Fig 326** *Grammatophora undulata* Ehrenberg × 710 **Figs 327, 328, 329** *Climacosphenia elongata* Bailey × 220 **Figs 330–332** *Licmophora abbreviata* Agardh × 710 Fig 330, valve view, 331, girdle view and 332, valve view different focus **Figs 333–334** *Climacosphenia moniligera* Ehrenberg ×215 **Fig 335** *Cl elongata* Bailey, valve view, base of cell

Distribution —Ephiphytic on marine algæ in the European coastal region from Mediterranean to North Sea; Greenland

XXXVIII Genus *Grammatophora* Ehrenberg

103 *Grammatophora undulata* Ehrenberg

(Figs 320, 324 and 326)

Kutzing, *Sp Alg*, 1849, p 121, Rabenhorst, *Fl Eu Alg* Pl I, 1864, p 303, De Toni, *Syll Alg*, Vol II, 1891-94, p 753; Boyer, *Syn N Am. Diat*, 1926, p 156, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931-32, p 48, fig 576

Frustules quadrangular with rounded angles, septa slightly undulate Valves linear-oblong, several times constricted in longer individuals, broad and widened in the middle, ends capitulate, 18-71 μ long, 10 5 μ broad. Striæ not clearly visible

Distribution —In the coasts of warmer seas, in Europe only in the Mediterranean, West Indies, Coast of Barbados, Pacific Ocean

Licmophorinæ

XXXIX Genus *Licmophora* Agardh

104 *Licmophora abbreviata* Agardh

(Figs 330 332)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931-32, p 66, fig 590

Podosphenia Lyngbyei Kutzing, *Sp Alg*, 1849, p 110,

Podosphenia abbreviata (Agardh) Kutzing, Rabenhorst, *Fl Eu Alg.*, Pl I, 1864, p 298,

Licmophora Lyngbyei (Kutzing) Grunow, Van Heurck, *Traité des Diatomées*, 1899, p 344, Gran, *Plank Nord*, *Bot Teil*, Bd VIII, 1908, p XIX 121, fig. 164, Boyer, *Syn N Am. Diat*, 1926, p 169, Lebour, *Plank Diat N Seas,* 1930, p 203, fig. 165; Allen and Cupp, *Plank Diat. Java Sea,* 1935, p. 153, fig 92

Licmophora Lyngbyei (Kützing) Grunow var *abbreviata* (Kützing) Grunow, De Toni, *Syll Alg.,* Vol. II, 1891-94, p 735;

Frustules in girdle view cuneate with strongly rounded angles Lower end attached to mucous stalk, cells forming colonies Setpa projecting into the cell. Valves oblanceolate with margins sub-parallel towards the apex and narrowed and elongated towards the base, 28-75 μ long and 8-11 μ broad Pseudoraphe distinct Striæ 12 in 10 μ at the base, about 15 near the apex

Distribution —The European coast; in North America, Atlantic and Pacific coasts, Baltic Sea.

XL Genus *Climacosphenia* Ehrenberg

105 *Climacosphenia moniligera* Ehrenberg

(Figs 322, 325 and 333-334)

Kützing, *Sp Alg*, 1849, p 114; De Toni, *Syll Alg*, Vol. II, 1891-94, p 740; Boyer, *Syn N. Am Diat*, 1926, p 171; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931-32, p. 89, fig 625

Climacosphenia australis Kutzing, *Sp Alg*, 1849, p 114.

Climacosphenia catena Shadbolt, *Descrip New Forms of Diat*, 1854 *a, p* 17, Pl I, fig 15

Frustules on short branched mucilage stalks, epiphytic, forming colonies; cuneate, narrow with upper margin rounded at the angles; base truncate. Septa two, with numerous foramina which are rectangular or subquadrate Valves clavate, rounded at the apex, elongated below, traversed longitudinally by two parallel lines; 98-308 μ long, 25 μ broad at the top and 7-10 μ at the base; striated, striæ on the valves 21 in 10 μ, finely punctate Striæ on girdle more coarsely punctate and about 15 in 10 μ.

Distribution —Very widely distributed and frequent in the coast of warmer and southern seas; in Europe in the Mediterranean only; Gulf of Mexico, Cuba, Barbados, Honduras and California

106 *Climacosphenia elongata* Bailey

(Figs. 323, 327-329 and 335)

De Toni, *Syll. Alg*, Vol II, 1891-94, p 739; Boyer, *Syn N Am. Diat.,* 1926, p. 172, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd. VII, Teil 2, 1931-32, p 90, fig 626.

Frustules cuneate, narrow, with slightly rounded angles and truncate bases. Valves clavate, rounded at the apex and very much elongated below, traversed by two parallel longitudinal lines, 784μ long Upper broader part short, 28μ broad and rather suddenly diminishing in breadth lower down and becoming linear; lower part about 9μ broad Valve striated, striæ fine, 21–24 in 10μ

Distribution —Florida, Atlantic coast southward

Sub-family Fragilarieæ

Fragilariinæ

XLI Genus *Fragilaria* Lyngbye

107 *Fragilaria oceanica* Cleve

(Figs 336–339)

Cleve, *Diat Arctic Sea*, 1873 *b*, p 22, Pl IV, fig 25, De Toni, *Syll Alg*, Vol II, 1891-94, p 685, Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 114, fig 154; Boyer, *Syn N Am. Diat*, 1926, p 185, Lebour, *Plank Diat N Seas*, 1930, p 193, fig 153, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931-32, p 148, fig 662

Fragilaria arctica Grunow, Cleve and Grunow, *Beiträge z Kenntniss Arct Diat*, 1880, p 110, Pl VII, fig 124

Frustules in girdle view linear-rectangular, forming a very compact ribbon-like chain Valves broadly lanceolate, with rounded ends, 11 5–31·5μ long, 6·5μ broad Transapical striæ delicate, towards the middle slightly fainter, 14 in 10μ, punctate, punctæ 15–18 in 10μ Pseudoraphe narrow, linear

Most of the earlier authors do not appear to have recognised the punctate nature of the striæ Cleve and Grunow (1880, p 110) alone state that the striæ in *F arctica* Gunow (Syn) are punctate near the margin

Distribution —Usually in the coast and among ice in polar seas; Davis Strait, Russia, Norway, Denmark, England and Gulf of Maine

XLII Genus *Rhaphoneis* Ehrenberg

108 *Rhaphoneis amphiceros* Ehrenberg

(Figs 340 and 341)

Rabenhorst, *Fl Eu Alg*, pt I, 1864, p 126, De Toni, *Syll Alg*, Vol II, 1891-94, p. 699; Boyer, *Syn N. Am Diat*, 1926, p 190; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931-32, p. 174, fig. 680; Allen and Cupp, *Plank Diat Java Sea*, 1935,, p 153, fig 93.

Doryphora amphiceros Kutzing, *Sp Alg*, 1849, p 50, W. Smith, *Syn Brit Diat*, Vol I, 1853, p 77.

Rhaphoneis lusitanica Rabenhorst, *Fl Eu Alg*, pt I, 1864, p. 126

Rhaphoneis amphiceros var *rhombica* Grunow, Van Heurck, *Traité des Diatomées*, 1899, p 330, Pl X, fig 394

Frustules lanceolate, inflated at the centre, 26·5–40μ long, 16 5–23μ broad Transapical striæ 9 in 10μ, punctate Pseudoraphe narrow, linear

Distribution—In the Atlantic coast of Europe, recorded also in brackish water

109. *Rhaphoneis discoides* sp nov

(Figs 347 and 350)

Frustules almost circular, 18–45μ in diameter Valve areolated. Areolæ close together, square, pentagonal or hexagonal in outline, somewhat radially arranged, all not of the same size, size slightly diminishing from the periphery to the centre, 6–9 in 10μ Pseudoraphe very narrow in the centre and slightly dilated at the poles Chromatophores numerous, disc-shaped

The cells grow attached to particles of dirt or other algæ Common in the plankton

This species differs from the others, *viz*, *Rhaphoneis Surirella* (Ehrenberg) Grunow, *R amphiceros* Ehrenberg, *R Belgica* Grunow, and *R. nitida* (Gregory) Grunow in being almost circular in shape whereas the above forms are boat-shaped or elliptical in outline The areolæ in the present form are close together, square, pentagonal or hexagonal in shape, radially arranged; all not of the same size, size slightly diminishing from the periphery to the centre, whereas the structure in the above forms is quite different—the valves being punctate, the punctæ placed apart and almost of the same size and round Chromatophores numerous, disc-shaped. The cell at first glance looks like a *Coscinodiscus*

Distribution—Plankton of the Madras coast.

XLIII. Genus *Synedra* Ehrenberg

Sub-genus *Ardissonia* De Notaris

110 *Synedra formosa* Hantzsch

(Figs 342, 343 and 348)

Boyer, *Syn N. Am Diat*, 1926, p 209, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931–32, p 233, fig 720.

Ardissonia formosa (Hantzsch) Grunow, De Toni, *Syll Alg*, Vol II, 1891-94, p 675.

Valves linear, gradually attenuate to the rounded ends, 140–300μ long, 18-20μ broad Transapical striæ robust, 9 in 10μ Cell wall porous, pores enclosed inside, and appearing as small openings Valves with three longitudinal ribs, hence, there being four series of openings, in the marginal series the openings lie more towards the sides Outer membrane finely areolate-punctate Between two ribs lie double series of areolæ

In the present form, in one of the specimens a disturbance in the arrangement of the transapical striæ in the middle was observed so that a sort of central nodule was seen (Fig 342)

Distribution —East Indian Archipelago, Honduras, Vera Cruz, Littoral in the coast of warmer seas In the region of the coast of south Europe

XLIV Genus *Thallassionema* Grunow

111 *Thallassionema nitzschioides* Grunow

(Figs 344-346)

Van Heurck, *Traité des Diatomées,* 1899, p 319, fig 75, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931-32, p 244, fig 725

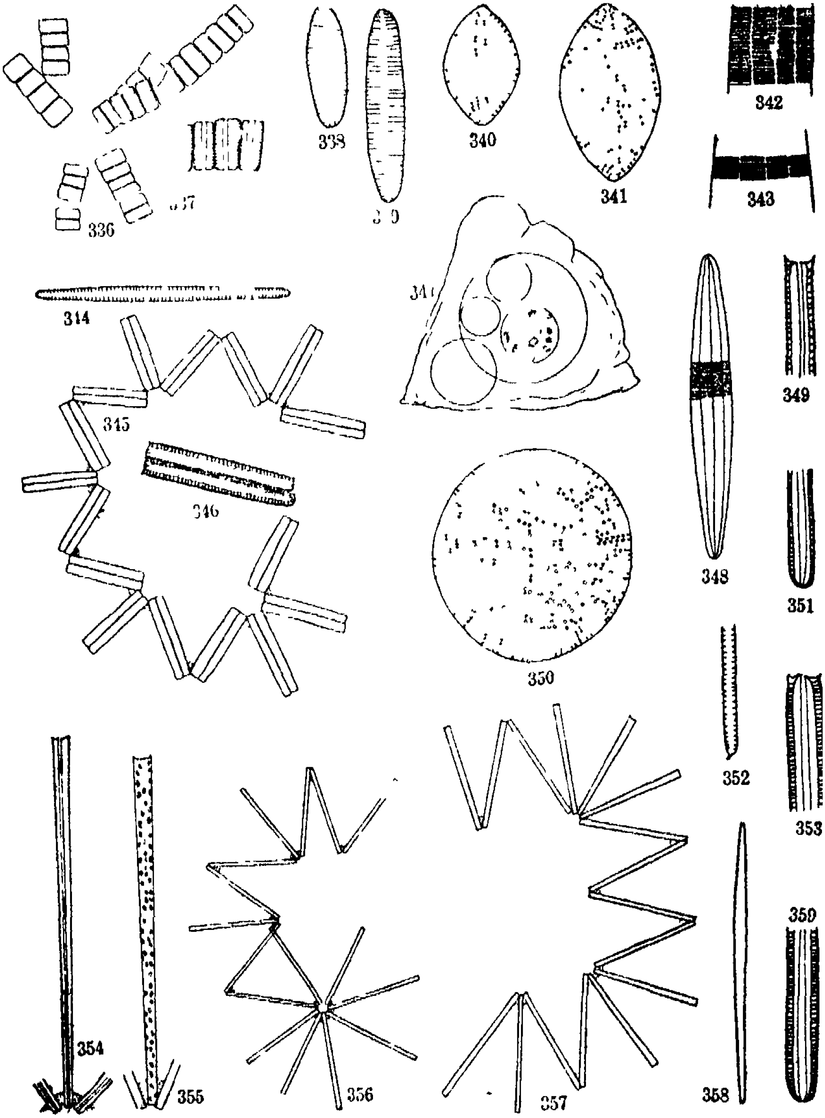
Thallassiothrix curvata Castracane, *Diat Chall*, 1886, p 55, Pl XXIV, fig 6; De Toni, *Syll Alg*, Vol II, 1891–94, p 672

Thallassiothrix nitzschioides Grunow, Van Heurck, *Traité des Diatomées,* 1899, p 314, Pl X, fig 434, Gran, *Nord Plank*, *Bot Teil,* Bd VIII, 1908, p XIX 117, fig 158, Lebour, *Plank Diat N. Seas,* 1930, p 199, fig 160, Allen and Cupp, *Plank Diat Java Sea,* 1935 p 154, fig 96

Thallassiothrix Frauenfeldii Cleve, *Plank Cilico Diat*, 1894–95, p. 6

Synedra nitzschioides Grunow, Boyer, *Syn N. Am Diat*, 1926, p 207

Frustules united into zig-zag chains Cells in girdle view linear-rectangular, in valve view linear-lanceolate, both poles alike, 21–64 5μ long, 3μ broad Marginal striæ 12 in 10μ



TEXT-FIGS 336-359.—Figs 336-339 *Fragilaria oceanica* Cleve ×460. In 338, note punctate nature of striæ Figs 340-341 *Rhaphoneis amphiceros* Ehrenberg. × 710. Figs. 342-343. *Synedra formosa* Hantzsch 342, Note disturbance in sculpturing and "Nodule"

×710; 343, × 930 Figs 344–346. *Thallassionema Nitzschioides* Grunow Figs 344, × 710; 345, ×460, 346, ×930 Fig 347 *Rhaphoneis discoides* sp nov A colony Cells attached to dirt particle ×460 Fig 348 *Synedra formosa* Hantzsch ×325 Fig 349 *Thallassiothrix Frauenfeldii* Grunow ×930 Fig 350 *Rhaphoneis discoides* sp nov × 710 Fig 351 *Thallassiothrix Frauenfeldii* Grunow ×930 Figs 352–353 *T longissima* Cleve et Grunow × 930 Fig 352, valve view, base of cell, 353, valve view distal end Figs 354–357 *T Frauenfeldii* Grunow. Fig 354, 355, ×460, 356, 357, colonies, ×150 Figs 358–359 *T longissima* Clevo et Grunow Fig. 358, two cells ×53, 359, ×930

Distribution —Pelagic in the coastal plankton of the European seas; in the North Atlantic abundant; North Sea, Holland, Russia, Norway, Sweden, Denmark, Germany, Finland, Mediterranean, North Atlantic coast of Europe and America and California

XLV Genus *Thallassiothrix* Cleve and Grunow

112 *Thallassiothrix longissima* Cleve and Grunow

(Figs 352, 353, 358 and 359)

Cleve and Grunow, *Beiträge z Kenntniss d Arct Diat*, 1880, p 108, De Toni, *Syll Alg*, Vol. II, 1891-94, p 672, Van Heurck, *Traité des Diatomées*, 1899, p 322, fig 78, Lebour, *Plank Diat N Seas*, 1930, p 199, fig 159, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931-32, p 247, fig 726

Synedra Thallassiothrix Cleve, *Diat Arct Sea*, 1873 *b*, p 22; Boyer, *Syn. N Am Diat*, 1926, p 207

Frustules free, thread like, often slightly curved Valve linear, ends rounded, 504–1624μ long, 2 5μ broad Marginal striæ about 14 in 10μ

Distribution —Oceanic plankton form in the North Atlantic, Arctic Sea, coasts of Scotland, Belgium, Russia, Germany, Norway, Sweden, Denmark, Mediterranean, California and Antarctic

113 *Thallassiothrix Frauenfeldii* Grunow

(Figs. 349, 351, 354–357 and 360)

Cleve and Grunow, *Beiträge z Kenntniss d Arct Diat*, 1880, p 109; Castracane, *Diat Chall*, 1886, p 54, Pl XIV, figs 7, 8, De Toni, *Syll Alg*, Vol II, 1891–94, p 672, Van Heurck, *Traité des Diatomées*, 1899, p 322, Pl. XXX, fig 839, Gran, *Nord Plank*, *Bot Teil*, 1908, p XIX 116, fig 159, Boyer, *Syn N Am Diat.*, 1926, p 214, Lebour, *Plank Diat N Seas*, 1930, p 200, fig 161; Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931–32, p 247, fig 727; Allen and Cupp, *Plank Diat. Java Sea*, 1935, p 154, fig. 97.

Asterionella Synedroeformis Greville, *Descrip New Genera and Sp. Hong Kong*, 1865 *b*, p 4, Pl V, figs 5, 6

Frustules forming stellate or zig-zag chains, or both tendency in the same chain, in girdle view linear, both the poles distinct and dissimilar, 98–210μ long Marginal striæ 12 in 10μ

Distribution.—Predominating in the warmer seas, coastal plankton of the Mediterranean; rare in the North Atlantic, coasts of England, Scotland, Belgium, Russia, Germany, Norway, Sweden, Denmark, North Atlantic coast of America

XLVI Genus *Asterionella* Hassal

114 *Asterionella japonica* Cleve

(Figs 361 and 371)

Gran, *Nord Plank*, *Bot Teil*, Bd VIII, 1908, p XIX 118, fig 160, Boyer, *Syn N Am Diat*, 1927, p 560, Lebour, *Plank Diat N Seas*, 1930, p 195, fig 155, Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931–32, p 254, fig 734; Allen and Cupp, *Plank Diat Java Sea*, 1935, p 155, fig 98, Venkataraman, *S I Diat*, 1939, p 309, fig 34

Asterionella glacialis Castracane, *Diat Chall*, 1886, p 50, Pl XIV, fig 1, De Toni, *Syll Alg*, Vol II, 1891–94, p 679

Frustules linear, narrow with parallel sides, broadened at the base, forming spiral colonies; 46–103μ long, 7-10μ broad The striæ are very difficult to discern.

Distribution—In the coastal plankton of the European seas widely distributed, and not rare, in the southern North Sea rather frequent; California, Java; also recorded in brackish water

Sub-order MONORAPHIDEÆ

Family Achnanthoideæ

Sub-family Cocconeideæ

XLVII Genus *Cocconeis* Ehrenberg

Sub-genus *Cocconeis*

115 *Cocconeis sigmoides* sp. nov

(Figs. 364 and 365)

Cells elliptic, 18μ long, 10μ broad Raphe-less valve with slightly radial transapical striæ, striæ about 18 in 10μ. The transapical striæ crossed by five longitudinal striæ Pseudoraphe very narrow Valve with raphe, with slightly radial punctate striæ, about 20 in 10μ Raphe somewhat sigmoid Axial area narrow. Central area slightly extended sideways

This species does not agree with any of the previously described species. The only form which comes near this is *Cocconeis scutellum* var *stauroneiformis* W Smith with which the present form shows a slight resemblance in structure, but the raphe in the present form is somewhat sigmoid whereas in the variety mentioned above the raphe is straight (*cf* Hustedt, 1931–32, p 339, fig 792)

Distribution — Plankton of the Madras coast

116 *Cocconeis littoralis* sp nov

(Figs 368–370)

Cells epiphytic on *Polysiphonia*, broadly elliptic, about 20–40μ long and 15–30μ broad Raphe-less valve with three well-defined hyaline areas demarcated by striated bands, the striæ being unequal in length, striæ with a dot-like thickening at the centre Marginal striæ also varying in length, about 21 in 10μ Valve with raphe with somewhat radial punctate striæ, the punctæ of one alternating with those of the adjacent one giving a sort of areolate appearance, striæ about 21 in 10μ Raphe sigmoid Axial area narrow dilating into a very small central area

This diatom does not agree with any other species so far described The valve with raphe shows a resemblance to the similar valve of *C dirupta* Gregory (*cf* Hustedt, 1931–32, p 354, fig 809 *a*) but differs from it the punctation of the striæ The punctæ in the present form alternate with those of the adjacent striæ and are close together presenting a hexagonal outline, whereas in *C dirupta* the punctæ are in wavy longitudinal series. Again, this valve shows a distant resemblance to that of *C decipiens* Cleve (1873 *a*, p. 14, Pl I, fig 6, Hustedt, 1931–32, p 353, fig 808), but differs from it in not having the central area extended sideways The raphe-less valve shows a superficial resemblance to that of *C heteroidea* Hantzsch (*cf* Hustedt, 1931–32, p 356, fig 811) In the latter Diatom there are five hyaline areas separated by striated bands, the middle one being larger than the others whereas in the present form there are only three areas separated by striated bands and these are of almost the same size

Distribution —Plankton of the Madras coast.

Sub-family Achnanthaceæ

XLVIII Genus *Achnanthes* Bory

Sub-genus *Microneis* Cleve

117 *Achnanthes Stromii* Hustedt

(Figs 362–363)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931–32, p 393, fig 841 **B**.

Valves lanceolate with scarcely drawn out rounded ends, 35–41 μ long, 13–17 μ broad Raphe less valve with robust transapical ribs, perpendicular to the middle line, crossed by delicate longitudinal ribs. Pseudoraphe long, linear Valve with raphæ with thread-like raphe, axial area narrow, widened in the middle a little Central area a small cross band, about half the valve breadth. Transapical striæ throughout radial, *18* in *10*μ, around the central nodule of varying length

Distribution —Norway

Sub-order BIRAPHIDEÆ

Family Naviculoideæ

Sub-family Naviculeæ

XLIX Genus *Mastogloia* Thwaites in W Smith (1856)

118 *Mastogloia exilis* Hustedt

(Figs 366 and 367)

Hustedt, Rabenhorst's *Kryptogamen-Fl*, Bd VII, Teil 2, 1931–32, p 553, fig 985

Valves lanceolate with more or less constricted, bluntly rounded ends, 19–21 μ long, and 10 μ broad Raphe straight, axial area very narrow, Central area widened and connected to two small half-lanceolate areas, together forming an H-shaped figure Transapical striæ fine, radial, 21–24 in 10 μ Loculi bigger in the middle, 1·5 μ broad, 5–6 in 10 μ. The outermost ones slightly smaller, all loculi with convex inner border

Distribution —Indo-Malayan Archipelago

119 *Mastogloia minuta* Greville

(Fig 372)

Greville, *New Diat West Ind*, 1857, p 12, Pl III, fig. 10; De Toni, *Syll. Alg.*, Vol II, 1891–94, p. 317; Cleve, *Syn Nav. Diat.*, 1895, p 151;

Boyer, *Syn N Am Diat*, 1927, p 339; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 160, fig 114.

Valves elliptical, with produced apiculate ends, 21–23 μ long, 8–10 μ broad Loculi 6 in 10 μ, equal in size, quadrate, extending to apiculate ends. Striæ fine

Distribution.—West Indies, Trinidad, Honduras, Bahamas

L Genus *Gyrosigma* Hassal

120 *Gyrosigma balticum* (Ehrenberg) Rabenhorst

(Figs 373–375)

Cleve, *Syn. Nav Diat*, 1894, p 118, Boyer, *Syn N Am Diat*, 1927, p 456; Hustedt, Pascher's *Susswasser-Fl*, 1930 *a*, p 224, fig 331, Venkataraman, *S I Diat*, 1939, p 318, figs 71 and 72

Pleurosigma balticum W Smith, *Syn Brit Diat*, Vol I, 1853, p 66, Pl XXII, fig 207, Pritchard, *Hist Infusoria*, 1861, p 917, Pl VIII, fig 33; Rabenhorst, *Fl Eu Alg*, 1864, pt I, p 235, De Toni, *Syll Alg*, Vol II, 1891–94, p. 249

Valves linear with obliquely truncate and obtuse ends, 294–332 μ long, 29–38 μ broad Raphe slightly excentric and somewhat flexuose. Central area small, oblique Transverse and longitudinal striæ equidistant, 12 in 10 μ.

Distribution.—In salt waters common, frequent in all the coasts; Baltic Sea, Atlantic and Pacific coasts of America; also recorded in brackish water in Madras

LI Genus *Pleurosigma* W Smith

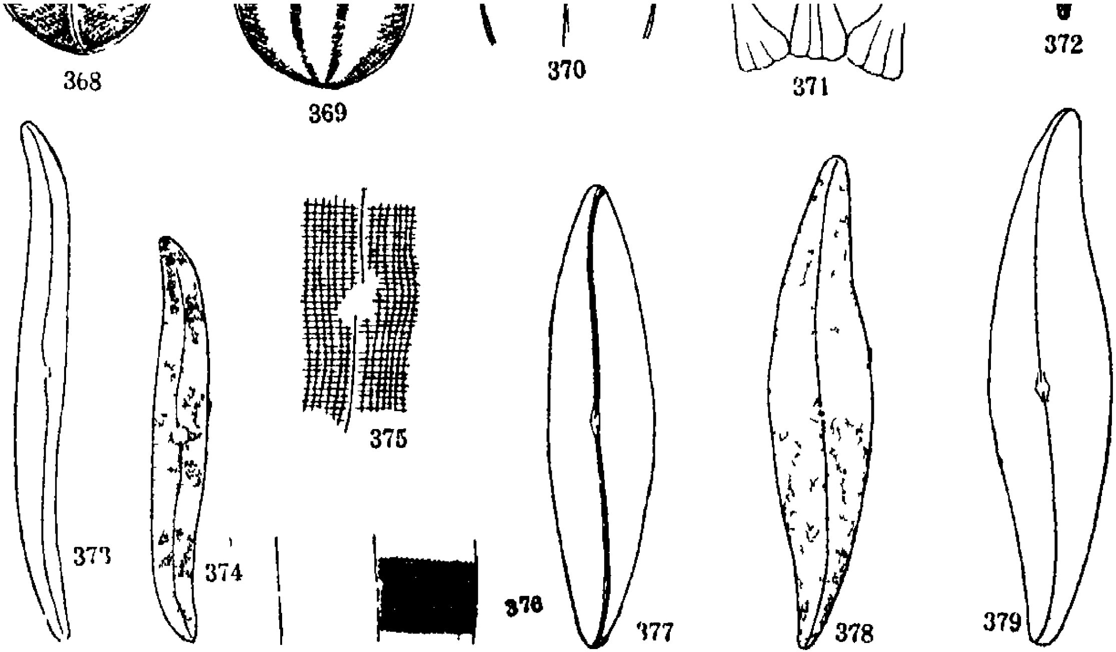
121 *Pleurosigma galapagense* Cleve

(Figs. 376 and 377)

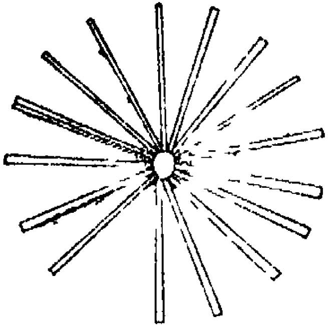
Cleve, *Syn Nav Diat*, 1894, p 36, Pl IV, fig. 16; Boyer, *Syn N Am Diat*, 1927, p 468

Valves scarcely sigmoid, lanceolate, tapering from the middle to the sub-acute ends, 74 5–140 μ long, 14–28 μ broad. Raphe slightly sigmoid, central. Transverse striæ 18 in 10 μ and oblique striæ 15 in 10 μ

Distribution.—Galapagos Islands.



Text-Figs 360–379 —Fig 360 *Thallassiothrix Frauenfeldii* Grunow ×83. Fig. 361. *Asterionella japonica* Cleve, a colony ×150 Figs 362–363. *Achananthes Stromii* Hustedt. ×930. Figs. 364–365. *Cocconeis sigmoides* sp nov. ×930 Figs. 366–367. *Mastogloia exilis.*



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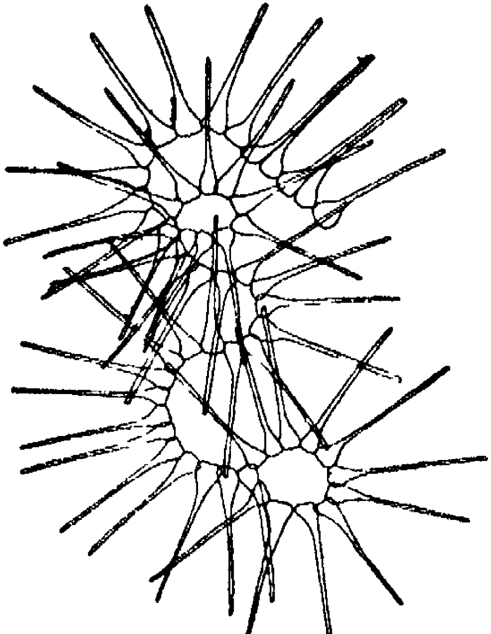

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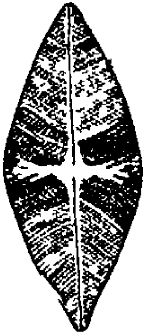

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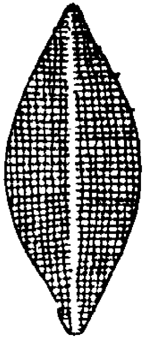

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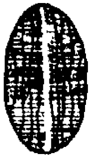

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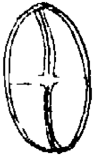

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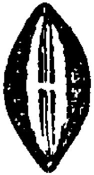

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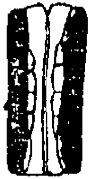

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Hustedt, valve and girdle views ×930 Figs 368–370 *Cocconeis littoralis* sp nov ×930. Fig. 370, finer structure of striæ Fig. 371 *Asterionella japonica* Cleve ×460 Fig 372 *Mastogloia minuta* Greville × 930 Figs 373–375 *Gyrosigma balticum* (Ehrenberg) Rabenhorst. Fig 373, × 150, 374, 150, 375, sculpturing, × 930 Figs 376–377 *Pleurosigma galapagense* Cleve Fig 376, ×930, 377, ×460 Figs 378 379 *P Normanii* Ralfs Fig 378, ×220, 379, ×328.

122 *Pleurosigma elongatum* W Smith

(Figs 380–382)

W Smith, *Notes Diat Pleurosigma*, 1852, Pl 1, fig 4, *Syn Brit Diat*, pt 1, Vol I, 1853, p. 64, Pl XX, fig 199, Rabenhorst, *Fl Eu Alg*, 1864, pt. I, p 234, Cleve and Grunow, *Beiträge z Kenntniss Arct Diat*, 1880, p. 50, Cleve, *Syn Nav Diat*, 1894, p 38, Van Heurck, *Traité des Diatomées*, 1899, p 253, Pl. VI, fig 262, Boyer, *Syn N Am Diat*, 1927, p 470, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 157, fig 105

Pleurosigma angulatum W Smith var *elongatum* (W Smith) Van Heurck, De Toni, *Syll Alg*, Vol II, 1891–94, p 223.

Valve slightly sigmoid, elongated, gradually attenuate, ends acute, 210–392 μ long, 32–39 μ broad Raphe central, slightly sigmoid Striæ 21 in 10 μ

Distribution—England, Atlantic coast of America, Java Sea

123 *Pleurosigma Normanii* Ralfs

(Figs 378, 379, 385 and 387)

Pritchard, *Hist Infusoria*, 1861, p. 919, Rabenhorst, *Fl Eu Alg*, 1864, pt I, p 236; Cleve and Grunow, *Beiträge z Kenntniss Arct Diat*, 1880, p. 14, p 52, Pl III, fig 67, Cleve, *Syn. Nav Diat*, 1894, p 40; De Toni, *Syll Alg*, Vol II, 1891–94, p 237, Boyer, *Syn N Am Diat*, 1927, p 471, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 157, fig 106

Pleurosigma affine Grunow var *Normanii* (Ralfs) Van Heurck, *Traité des Diatomées*, 1899, p 252

Valve broadly lanceolate, slightly sigmoid with sub-acute ends 196–322 μ long, 41–60 μ broad Transverse striæ 21 in 10 μ, oblique striæ 18 in 10 μ

Distribution—Europe, Atlantic coast of America, Java Sea

124. *Pleurosigma angulatum* (Quekett) W. Smith
var *strigosa* (W Smith) Van Heurck

(Figs. 383–384)

Van Heurck, *Traité des Diatomées*, 1899, p 251, Pl VI, fig. 261; Cleve, *Syn. Nav Diat*, 1894, p 41; De Toni, *Syll Alg*, Vol II, 1891–94, p 233; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 158, fig. 108

Pleurosigma strigosum W. Smith, *Notes Diat Pleurosigma*, 1852, p. 7, Pl I, fig 6; *Syn Brit Diat*, Vol I, 1853 p 64, Pl XXI, fig 203; Rabenhorst, *Fl Eu Alg*, 1864, pt I, p 232; Boyer, *Syn. N Am Diat*, 1927, p 472.

Pleurosigma (*strigosum* var ?) *convexum* Grunow, Cleve and Grunow, *Beiträge z Kenntniss Arct Diat.*, 1880, p 50, De Toni, *Syll Alg*, Vol. II, 1891-94, p 233

Valves lanceolate, slightly sigmoid, ends sub-acute, 116μ long, 16·5μ broad Raphe more sigmoid than valve, excentric near the ends. Transverse and oblique striæ equidistant, 18-21 in 10μ

Distribution.—England, Italy, Sicily, Finmark, Adriatic Sea, Mediterranean, Baltic

125 *Pleurosigma aestuarii* Brébisson

(Figs. 386, 393 and 394)

W Smith, *Syn. Brit Diat*, Vol I, 1853, p 65, Pl XXXI, fig 275; Rabenhorst, *Fl Eu Alg*, 1864, pt I, p 234; Cleve, *Syn Nav Diat*, 1894, p 42; Boyer, *Syn N Am Diat*, 1927, p 472

Pleurosigma angulatum var *æstuarii* (Brébisson) Van Heurck, *Traité des Diatomées*, 1899, p 251, Pl VI, fig 258; De Toni, *Syll. Alg*, Vol II, 1891-94, p 232

Valves lanceolate, gently sigmoid, with slightly produced ends 60-83μ long, 16-20μ broad Raphe more sigmoid than the valve; excentric. Transverse and oblique striæ equidistant 18-21 in 10μ

Distribution —England, Finmark, Italy, Lusitania, France, Atlantic and Pacific coasts of America

126 *Pleurosigma carinatum* Donkin

(Fig 388)

Donkin, *Marine Diat*, 1858, p. 23, Pl III, figs 5 *a* and *b*; Cleve, *Syn Nav Diat*, 1894, p. 44; Boyer, *Syn N. Am Diat*, 1927, p 475

Donkinia carinatum Ralfs, Pritchard, *Hist Infusoria*, 1861, p 921, pt I, Pl. VIII, fig. 49, Rabenhorst, *Fl Eu Alg*, 1864, pt. I, p. 242, Van Heurck, *Traité des Diatomées*, 1899, p 248, Pl XXXV, fig 286

Valves convex, linear-lanceolate, acute at the ends, 53-60μ long, 8μ broad Raphe on elevated keel, diagonal in the centre and closely following the margins Striæ 21-24 in 10μ

Distribution.—England, Davis Strait.

127. *Pleurosigma directum* Grunow var. *membranacea* var. nov.

(Figs 389-392)

Frustules hyaline, membraneous, easily breaking down Valves lanceolate, slightly sigmoid, 238–518 μ long, 39-56 μ broad Raphe very faint, axial area very narrow, central area almost invisible Structure on the valve very difficult to make out; punctate as in the other species Chromatophores two long dissected bands. This form differs from the type (*cf.* Karsten, 1907, p 127, Taf XVIII, fig 5 *a, b, c*), in having the raphe more sigmoid Further the cells taper somewhat more from the centre to the poles than in the type

Distribution —Plankton of Madras coast

LII Genus *Caloneis* Cleve

128. *Caloneis madraspatensis* sp nov

(Fig 396)

Valves linear-elliptical with slight transapical contraction of the border at the centre and blunt, boat-like rounded poles Raphe straight Axial area small, lanceolate, dilating into a large elliptical central area, which has on either side of the nodule a crescent-shaped figure, in which the striæ continue faintly Striæ 15 in 10 μ, near the margin cut by a long line

This form does not resemble any of the forms so far described in all respects. However, it resembles *C Schroederi* Hustedt (1930 *a*) in shape and *C. Schumanniana* (Grunow) Cleve in structure

Distribution —Plankton of Madras coast

LIII Genus *Diploneis* Ehrenberg

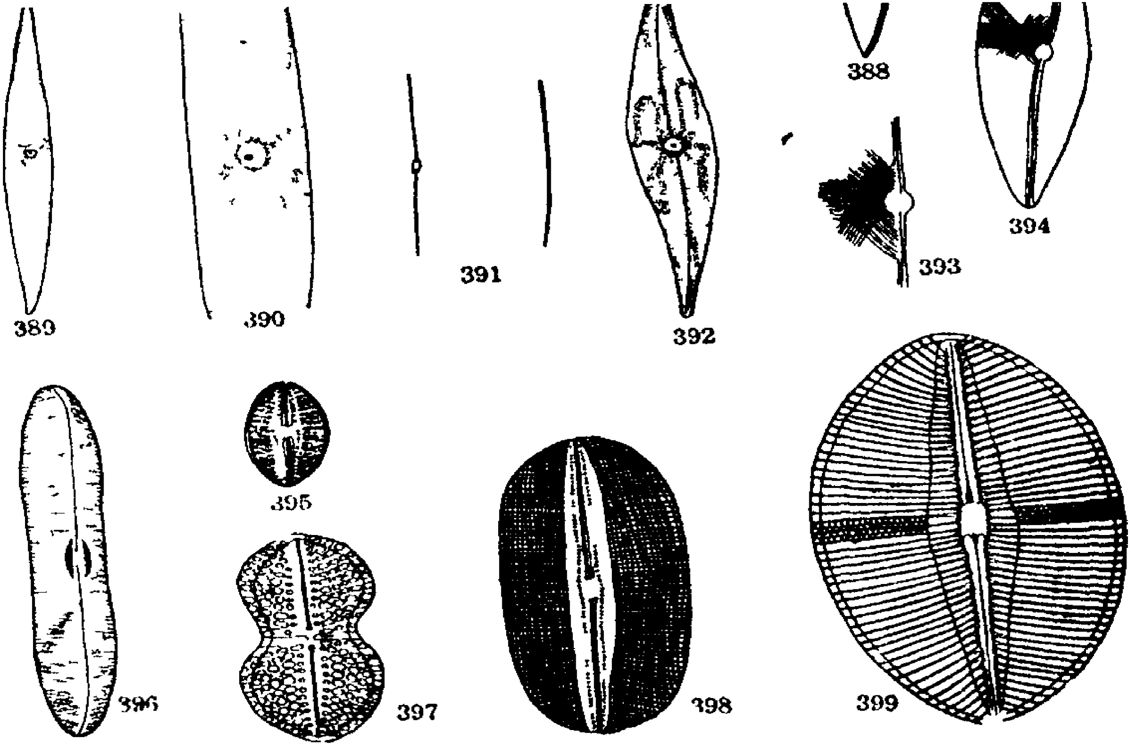
129. *Diploneis Weissflogii* (A Schmidt) Cleve

(Fig 397)

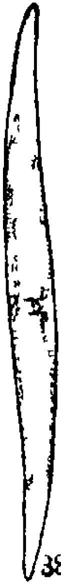
Cleve, *Syn Nav Diat*, 1894, p 91; Boyer, *Syn N Am Diat*, 1927, p. 351

Navicula Weissflogii A Schmidt, Van Heurck, *Traité des Diatomée*, 1899, p 194, Pl. III, fig 148; De Toni, *Syll Alg*, Vol II, 1891-94, p 75; Allen and Cupp, *Plank Diat Java Sea*, 1935, p. 156, fig 100.

Valves strongly constricted, with sub-elliptical ends, 28–54 μ long, 10–24 μ broad, and at the constriction 7-14 μ broad. Central nodule with



Text-Figs 380–399 —Figs 380–382. *Pleurosigma elongatum* W Smith Fig. 380, 381, ×1
×930 Figs 383–384 *P angulatum* var. *strigosa* (Smith) Van Heurck. Fig 383, ×9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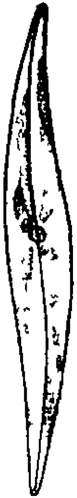
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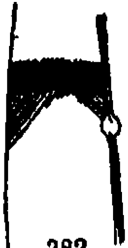
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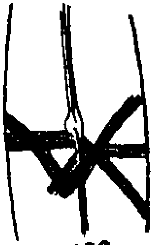
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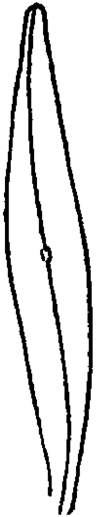
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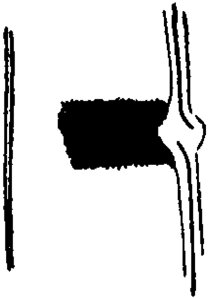
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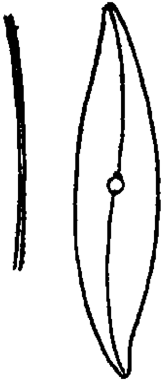
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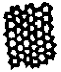
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Fig. 387 *Pleurosigma Normanii* Ralfs Schematic representation of sculpturing. Fig. 388 *P carinatum* Donkin × 710 Figs 389–392 *P directum* Grunow var *membranacea* var nov Fig. 389, × 150, 390, × 220, 391, × 460, 392, × 220 Figs 393–394 *P. æstuarii* Brébisson Fig. 393, ×930, 394, × 460 Fig 395 *Diploneis puella* (Schumann ?) Cleve × 930 Fig 396 *Caloneis madraspatensis* sp nov × 710 Fig 397 *Diploneis Weissflogii* (A Schmidt) Cleve. ×930. Fig. 398 *Diploneis fusca* var *subrectangularis* Cleve. × 710 Fig. 399 *D Smithii* (Brébisson) Cleve ×930

approximate horns Transverse costæ 9 in 10μ, crossed by equidistant longitudinal costæ curved outwards in the middle of the valve

Distribution —Sandwich Islands, Singapore, Java, Ceylon and Blankenberge

130 *Diploneis puella* (Schumann 1867 ?) Cleve

(Fig 395)

Cleve, *Syn Nav Diat*, 1894, p 92, Boyer, *Syn N Am Diat*, 1927, p 355, Hustedt, Pascher's *Susswasser-Fl*, 1930 *a*, p 250, fig 394.

Navicula elliptica Kutzing var ? *puella* Schumann, De Toni, *Syll Alg.*, Vol II, 1891-94, p 90

Navicula (*Diploneis*) *puella* Schumann, Schönfeldt, Pascher's *Susswasser-Fl*, 1913, p 67, fig 121

Valves elliptical, 16 5μ long, 10μ broad. Central nodule large, quadrate, horns clear Furrows narrow, in the middle scarcely broader, slightly dilated around the central nodule Costæ slightly radial, 12 in 10μ, with alternating double rows of alveoli visible on careful examination.

Distribution —Europe, recorded from brackish water also

131 *Diploneis fusca* Gregory var *sub-rectangularis* Cleve

(Fig 398)

Cleve, *Syn Nav Diat*, 1894, p 93

Navicula fusca Gregory var *suo-rectangularis* Cleve, Van Heurck, *Traité des Diatomées*, 1899, p. 199, Pl. XXVI, fig 742

Valve more or less rectangular, ends broadly rounded, 57μ long and 25μ broad Central nodule clear Furrows broad, gradually tapering from the middle and crossed by faint prolongations of the costæ Costæ 12 in 10μ, with alternating alveoli which are more or less quadrate, alveoli 12-15 in 10μ

Distribution.—England, Blankenberg, Denmark

132 *Diploneis Smithii* (Brébisson) Cleve

(Fig. 399)

Cleve, *Syn Nav Diat*, 1894, p 96; Boyer, *Syn N Am Diat*, 1927, p 354, Hustedt, Pascher's *Susswasser-Fl*, 1930 *a*, p 253, fig 402

Navicula Smithii Brébisson, W Smith, *Syn Brit Diat*, Vol II, 1856, p. 92; Rabenhorst, *Fl Eu Alg*, 1864, pt I, p 178; Van Heurck, *Traité des Diatomées*, 1899, p. 192, Pl IV, fig 151, *a, b*

Navicula (Diploneis) Smithii Brébisson, Schönfeldt, Pascher's *Süsswasser-Fl.*, 1913, p 69, fig 124

Navicula elliptica W Smith, *Syn. Brit Diat*, Vol. I, 1853, p 47, Pl. XVII, fig 152

Valve elliptical with broadly rounded poles and strongly convex sides, 58 μ long, 35 μ broad. Central nodule more or less well developed, small, rounded quadrate Horns robust Furrows lanceolate, diminishing in breadth from the middle towards the poles Transapical costæ 9 in 10 μ, radial, with alternating double rows of alveoli Alveoli in two oblique rows which cross each other

Distribution—England, America, brackish and marine

133 *Diploneis robustus* sp nov

(Fig 400)

Valves linear-elliptical with broadly rounded poles; sides slightly drawn in in the middle, 60–74 μ long and 23-28 μ broad Raphe straight, narrow Central nodule quadrate, wavy at the sides, with well-developed horns. Furrows narrow diminishing in breadth from the centre towards the poles Transapical costæ very well developed, robust, swollen at the tip; somewhat radially arranged, 6 in 10 μ Two rows of alveoli on either side of the central axial area, one against each costa, but interrupted in the middle

This form resembles *Diploneis interrupta* (Kutzing) Cleve (*cf* Hustedt, 1930 *a*, p 252, fig 400) in the nature of its costæ But *D interrupta* is linear elliptical in outline with highly constricted sides, the constriction nearly dividing the cell into two elliptical halves, whereas the present form is only slightly drawn in at the sides The striæ in the former are interrupted in the middle whereas they are not interrupted in the present form.

Distribution—Plankton of the Madras coast

LIV Genus *Navicula* Bory

Section Lineolatæ Cleve

134 *Navicula longa* (Gregory) Ralfs

(Fig 401)

Pritchard, *Hist Infusoria*, 1861, p 906, De Toni, *Syll Alg*, Vol II, 1891-94, p 17, Van Heurck, *Traité des Diatomées*, 1899, p 185, Pl XXV, fig 716, Boyer, *Syn N Am Diat*, 1927, p 397

Pinnularia longa Gregory, *Post Tertiary Diat*, 1856, p 47, Pl V, fig 18, Rabenhorst, *Fl Eu Alg*, 1864, pt I, p 218

Valves rhombic elongated with acute ends, 55 μ long, 10 μ broad Axial area narrow; central area small Striæ 9-12 in 10 μ radiate, lined across, lines about 30 in 10 μ

Distribution -- Scotland, Atlantic coast of America, and Colombo

Section Lyratæ Cleve

135 *Navicula Hennedyii* W Smith

(Fig 402)

W Smith, *Syn Brit Diat*, Vol II, 1856 p 93, Gregory, *Post-Tertiary Diat*, 1856, p 40, Pl V, fig 3, Pritchard, *Hist Infusoria*, 1861, p 898, Pl VII, fig 69, Rabenhorst, *Fl Eu Alg*, 1864, pt I, p 178, De Toni, *Syll Alg*, Vol II, 1891-94, p 103, Cleve, *Syn Nav Diat*, 1894, p 57, Van Heurck, *Traité des Diatomées*, 1899, p 204, Pl IV, fig 160, Boyer, *Syn N Am Diat*, 1927, p 413

Valves elliptical, 39 5-61 5 μ long, 21 5-36 5 μ broad Lateral areas broad, semilanceolate, with almost parallel inner margins Striæ 12-15 in 10 μ.

Distribution —England, Belgium, Italy, Greenland, Spitzbergen, Finmark, Lusitania, Adriatic, North America and Ceylon.

Navicula Hennedyii W Smith var *nebulosa* (Gregory) Cleve

(Fig 404)

Cleve, *Syn Nav Diat*, 1895, p 58, Van Heurck, *Traité des Diatomées*, 1899, p 204, Pl. XXVII, fig 755, Boyer, *Syn N Am. Diat*, 1927, p 413.

Navicula nebulosa Gregory, *Diat Firth of Clyde*, 1857 *b*, p 480, Pl IX, fig. 8; De Toni, *Syll Alg*, Vol II, 1891-94, p 107

Valves somewhat elliptical, 33 μ long, 10 μ broad. Lateral areas clear, prominent, suddenly narrowed at the ends, smooth. Striæ about 18 in 10 μ, punctate.

Distribution.—Iceland, Ireland, North Sea, and probably Belgium

136 *Navicula clavata* Gregory

(Fig. 403)

Gregory, *Post-Tertiary Diat.*, 1856, p 46, Pl. V, fig. 17; Cleve, *Syn Nav Diat*, 1895, p 61

Navicula Hennedyii W Smith var *clavata* Van Heurck, *Traité des Diatomées*, 1899, p 204

Navicula Hennedyii W Smith var ? *clavata* (Gregory ?) De Toni, *Syll Alg*, Vol II, 1891-94, p 104

Valves elliptical with rostrate ends, 50–66 5 μ long, 30–36·5 μ broad. Marginal striæ 12-15 in 10 μ, axial striæ 15-18 in 10 μ.

Distribution.—Blankenberg, England, Iceland

137 *Navicula forcipata* Greville

(Fig 405)

Greville, *Descrip New Sp Brit Diat*, 1859 *a*, p 83, Pl VI, figs 10 and 11; De Toni, *Syll Alg*, Vol II, 1891-94, p 97, Cleve, *Syn Nav Diat*, 1895, p 65, Van Heurck, *Traité des Diatomées*, 1899, p 203, Pl IV, fig 163; Boyer, *Syn N Am Diat*, 1927, p 416

Valves elliptical with rounded ends, 30 μ long and 20 μ broad. Lateral areas narrow, constricted in the middle, convergent at the ends. Striæ 12 in 10 μ; closely punctate

Distribution.—England, Belgium, Adriatic Sea, Atlantic and Pacific coasts of America

LV Genus *Pinnularia* Ehrenberg

Section Distantes Cleve

138. *Pinnularia alpina* W Smith

(Fig 406)

W. Smith, *Syn. Brit Diat*, Vol I, 1853, p 55, Pl XVIII, fig. 168; Cleve, *Syn. Nav. Diat*, 1895, p. 81, Schönfeldt, Pascher's *Süsswasser-Fl.*, 1913, p. 105, fig. 225; Hustedt, Pascher's *Süsswasser-Fl.*, 1930 *a*, p. 324, fig. 594

Navicula alpina Ralfs, Pritchard, *Hist Infusoria*, 1861, p 906, Rabenhorst, *Fl Eu Alg*, pt I, 1864, p. 215, De Toni, *Syll Alg.*, Vol II, 1891–94, p 16; Van Heurck, *Traité des Diatomées*, 1899, p 169, Pl XXV, fig 705

Valve elliptic-lanceolate with rounded obtuse ends, 85μ long and 28 5μ broad Axial area somewhat wide, lanceolate Striæ broad, smooth, radiate, transverse at the ends, 4 in 10μ

Distribution —France, Iceland and Scotland

LVI Genus *Trachyneis* Cleve

139 *Trachyneis aspera* Ehrenberg var *genuina* Cleve

(Fig 408)

Cleve, *Syn Nav Diat*, 1894, p 191, Boyer, *Syn N Am Diat*, 1927, p 428

Navicula aspera Ehrenberg, De Toni, *Syll Alg*, Vol II, 1891-94, p 109, Van Heurck, *Traité des Diatomées*, 1899, p 205, Pl IV, fig 165

Valves linear-lanceolate, with obtuse ends, 52–224μ long, and 10·5–21·5μ broad Axial area broad, stauroid, truncate, not reaching the sides Transapical striæ alveolate, 10 in 10μ Longitudinal striæ very fine, 24 in

Distribution —Britain, Belgium, Mediterranean, Adriatic Sea, America, Borneo, Ceylon and Aden

140 *Trachyneis Antillarum* Cleve

(Fig 409)

Cleve, *Syn Nav Diat*, 1894, p 193, Boyer, *Syn N Am Diat*, 1927, p. 429

Alloioneis (?) *Antillarum* Cleve and Grunow, Cleve, *Diat West Ind Arch*, 1878, p 8 Pl II, fig 11,

Scoliopleura Antillarum (Cleve and Grunow) De Toni, *Syll Alg*, Vol II, 1891–94, p. 265

Valves linear-elliptical with obtuse ends, 89 5-114μ long, 33-35 5μ broad Raphe excentric, axial area more or less broad, irregularly linear and unilateral Transverse striæ in radial rows, alveolate, 9–12 rows in 10μ

Distribution —West Indies, Florida, Campeche Bay and Indian Ocean.

Sub-family Amphiproroideæ

LVII Genus *Amphiprora* Ehrenberg

141. *Amphiprora gigantea* Grunow
var *sulcata* (O'Meara) Cleve

(Figs 410 and 413)

Cleve, *Syn Nav Diat*, 1894, p 18, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 160, fig 113

Amphiprora sulcata O'Meara, *On Some New Sp Amphiprora*, 1871, p 22, Pl III, fig 3, De Toni, *Syll Alg*, Vol II, 1891-94, p 334

Cells strongly constricted. Keel with hyaline margin Junction line curved like a bow Cells 64-91 μ long Keel punctæ forming obliquely decussating rows, 15 rows in 10 μ Striæ curved Connecting zone with numerous longitudinal divisions Striæ on the connecting zone 18 in 10 μ.

Distribution —Java Sea and Indian Ocean.

LVIII Genus *Tropidoneis* Cleve

142 *Tropidoneis semistriata* Grunow

(Figs. 411 and 412)

Cleve, *Syn Nav Diat*, 1894, p. 27, Pl III, figs 9, 10, 11.

Valve membraneous, lanceolate, acute, in girdle view slightly constricted, 124 μ long and 18 μ broad Keel somewhat excentric Striæ 18 in 10 μ, not reaching the margin of the valve

Sub-family Gomphocymbelloideæ

LIX Genus *Amphora* Ehrenberg

Sub-genus *Oxyamphora* Cleve

143 *Amphora lineolata* Ehrenberg

(Fig. 407)

Kützing, *Sp Alg*, 1849, p 94; Pritchard, *Hist Infusoria*, 1861, p 883; Rabenhorst, *Fl Eu Alg*, pt. I, 1864, p 92; De Toni, *Syll Alg*, Vol II, 1891-94, p 394; Cleve, *Syn Nav. Diat*, 1895, p 126; Van Heurck, *Traité des Diatomées*, 1899, p 138, Pl I, fig 10; Boyer, *Syn. N Am Diat*, 1927, p. 264, Hustedt, Pascher's *Susswasser-Fl*, 1930 *a*, p 346, fig. 636.

Amphora? *tenera* W Smith, *Syn. Brit. Diat*, Vol I, 1853, p 20, Pl. XXX, fig. 252.

Amphora plicata Gregory, *Post-Tertiary Diat*, *Glenshira*, 1857 *a*, p. 70, Pl. I, fig 31

Frustules hyaline, weakly silicified, in girdle view rectangular-elliptical, with slightly convex sides, 66–93 μ long, 31 5–52 5 μ broad (girdle view). Intercalary bands numerous, 10 in 10 μ Raphe with straight branches, which run back from the central nodule dorsal-ward Axial area narrow, central area absent. Transapical striæ very slightly radial 18–21 in 10 μ, finely punctate.

Distribution.—Blankenberg, England, Sweden, Tropical America

144 *Amphora decussata* Grunow

(Figs 414 and 415)

De Toni, *Syll Alg*, Vol II, 1891-94, p 378; Cleve, *Syn Nav Diat*, 1895, p 128, Pl IV, fig 10, Boyer, *Syn. N Am Diat*, 1927, p 267; Allen and Cupp, *Plank. Diat Java Seas*, 1935, p 161, fig 116

Frustules thin, elliptical, with truncate ends, 78–99 5 μ long, 28–50 μ broad (girdle view) Zone with numerous divisions 10–12 in 10 μ, very finely transversely striate. Raphe close to the ventral margin Central nodule dilated into a transverse stauros Dorsal side with oblique striæ 15–18 in 10 μ, turned in opposite directions from the central stauros, crossed by undulating narrow transverse bands, giving the striæ a punctate appearance, the punctæ being slightly elongated.

Distribution —Honduras, coast of Barbadoes and Java

145. *Amphora ostrearia* Brébisson

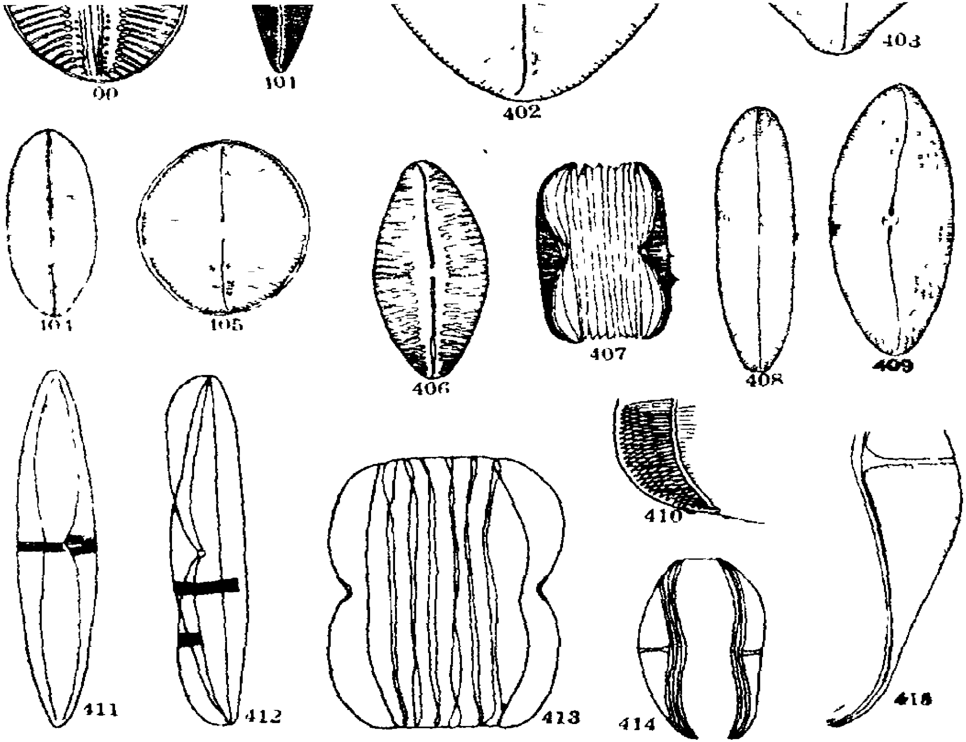
(Figs 418 and 419)

Kutzing, *Sp Alg*, 1849, p 94, Pritchard, *Hist Infusoria*, 1861, p 881; Rabenhorst, *Fl Eu Alg*, pt I, 1864, p 88, De Toni *Syll Alg*, Vol II, 1891-94, p 376; Cleve, *Syn Nav Diat*, 1895, p 129, Van Heurck, *Traité des Diatomées*, 1899, p 139, Pl I, fig 1; Boyer, *Syn N Am Diat*, 1927, p. 265

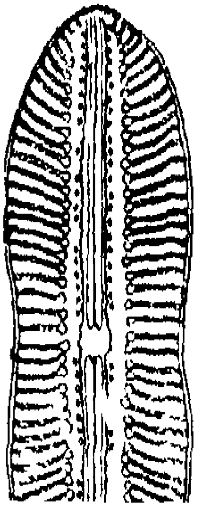
Amphora quadrata Brébisson, Kutzing, *Sp Alg*, 1849, p 95, Pritchard, *Hist Infusoria*, 1861, p. 881

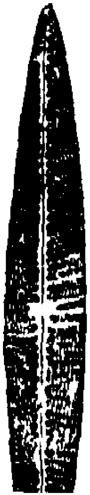
Amphora ostrearia var *quadratæ* (Brebisson) Rabenhorst, *Fl. Eu Alg*, pt. I, 1864, p 88; De Toni, *Syll Alg*, Vol II, 1891–94, p 376

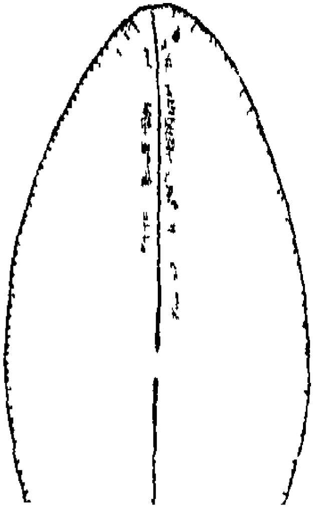
Amphora membranacea W Smith, *Syn Brit. Diat*, Vol. I, 1853, p. 20, Pl II, fig 29; Pritchard, *Hist Infusoria*, 1861, p. 881, Rabenhorst, *Fl. Eu. Alg.*, pt. I, 1864, p. 87; De Toni, *Syll. Alg*, Vol II, 1891–94, p. 377.

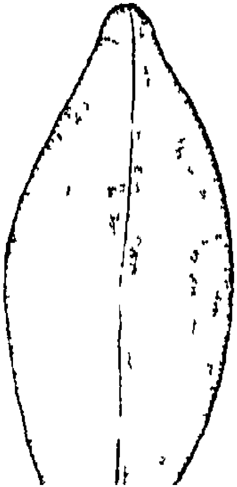


Text-Figs 400–415.—Fig 400 *Diploneis robustus* sp nov. ×930. Fig 401 *Navicula onga* (Gregory) Ralfs ×930 Fig. 402 *N Hennedyii* W Smith ×930 Fig 403 *N. clavata* Gregory. ×710 Fig 404 *N Hennedyii* var *nebulosa* (Gregory) Cleve × 930 Fig. 405. *N forcipata* Greville ×930 Fig 406 *Pinnularia alpina* W Smith ×428 Fig. 407 *Amphora*









lineolata **Ehrenberg ×460. Fig 408 *Trachyneis aspera* Ehrenberg var *genuina* cleve ×428 Fig 409 *T antillarum* Cleve × 460 Fig 410 *Amphiprora gigantea* var *sulcata* (O'Meara) Cleve, sculpturing. ×390 Figs 411–412 *Tropidoneis semistriata* Grunow ×460 Fig 413 *Amphiprora gigantea* var *sulcata* (O'Meara) Cleve × 710 Figs 414–415 *Amphora decussata* Grunow Fig. 414, ×325, 415, ×930**

Amphora elegans Gregory, *Post-Tertiary Diat Glenshira*, 1857 *a*, p 70, Pl I, fig. 30; Pritchard, *Hist Infusoria*, 1861, p 881, Rabenhorst, *Fl Eu Alg*, pt. I, 1864, p 87; De Toni, *Syll Alg*, Vol II, 1891-94, p 381

Amphora litoralis Donkin, *Mar Diat Northumberland*, 1858, p 30, Pl. III, fig. 15, Rabenhorst, *Fl Eu Alg*, pt I, 1864, p 89, De Toni, *Syll Alg*, Vol. II, 1891-94, p. 380

Frustules weakly silicified, elliptical to quadrate in outline Zone with numerous divisions, striated. Valve of various shapes depending on position, 68-79 μ long and 18–21 5 μ broad, striated, striæ 12 in 10 μ, punctate

Distribution –Calvados, France (in oysters), England

LX Genus *Cymbella* Agardh

146 *Cymbella marina* Castracane

(Fig 416)

Castracane, *Diat Chall*, 1886, p 21, Pl XXVII, fig 13, De Toni, *Syll Alg*, Vol II, 1891–94, p 359

Cells linear, ventral margin straight, dorsal arcuate Raphe somewhat broad. Axial area narrow, central area slightly dilated Striæ radial, 15 in 10 μ.

Distribution.—Japanese Sea

Family Nitzschiaceæ

Sub-family Nitzschioideæ

LXI Genus *Bacillaria* Gmelin

147. *Bacillaria paradoxa* Gmelin

(Figs 417, 421 and 427)

W. Smith, *Syn. Brit Diat*, Vol II, 1856, p 10, Pl XXXII, fig 279, Pritchard, *Hist Infusoria*, 1861, p 784, Pl IX, figs 166, 167; De Toni, *Syll Alg.*, Vol II, 1891–94, p 493, Gran. *Nord Plank., Bot Teil*, Bd VIII, 1908, p. XIX 131, fig 178, Schönfeldt, Pascher's *Susswasser-Fl.*, 1913, p 149, fig 328; Karsten, *Nat Pflanzenfam*, 1928, p 294, figs. 100, 190, 399, Lebour, *Plank Diat N Seas*, 1930, p 211, fig. 175, Hustedt, Pascher's

Susswasser-Fl, 1930 *a*, p 396, fig 755, Allen and Cupp, *Plank Diat. Java Sea*, 1935, p 162, fig 117, Venkataraman, *S I Diat.*, 1939, p. 351, figs 144 and 145

Nitzschia paradoxa (Gmelin) Grunow, Van Heurck, *Traité des Diatomées*, 1899, p 392, Pl XVI, fig 518

Nitzschia paxillifer (O F Muller) Heib, Boyer, *Syn N Am Diat.*, 1927, p 509

Cells in girdle view linear and rectangular, united by their valves to form a mat-like colony, the individual cells of which exhibit gliding movements in the living condition. Valves linear spindle-shaped in outline, 112–196 μ long, 6·5–9 μ broad Kiel punctæ 7–8 in 10 μ Transapical striæ fine 21 in 10 μ

Distribution—European coast, Californian coast, Java Sea, recorded from brackish water in Madras

LXII Genus *Nitzschia* Hassal

Section Panduriformis Grunow

148 *Nitzschia panduriformis* Gregory var *continua* Grunow

(Fig 425)

Cleve and Grunow, *Beiträge z Kenntniss Arct. Diat*, 1880, p 71, Pl. V, fig 92; De Toni, *Syll Alg*, Vol II, 1891–94, p. 502; Boyer, *Syn N Am. Diat*, 1927, p 498

Cell elliptical, slightly constricted in the middle, extremities somewhat pointed, 20–35 μ long and 10–12 μ broad. Keel punctæ 9–12 in 10 μ. Valve finely punctate, punctæ 21–24 in 10 μ, arranged in three line system.

Distribution—Arctic Sea, Adriatic, Mediterranean, Atlantic coast of America and West Indies

Section Lineares (Grunow) Hustedt erw

149 *Nitzschia vitrea* Norman

(Figs 420 and 422)

Norman, *On some undescrib Sp Diat*, 1861, p 7, Pl II, fig 4; Rabenhorst, *Fl Eu Alg*, pt I, 1864, p 152; Cleve and Grunow, *Beiträge z. Kenntniss. Arct. Diat.*, 1880, p 93, De Toni, *Syll Alg*, Vol II, 1891–94, p. 536; Van Heurck, *Traité des Diatomées*, 1899, p 399, Pl XVI, fig. 544; Boyer, *Syn. N Am Diat*, 1927, p. 519; Kolbe, *Brackwasser-Diatomeen*, 1927, p. 98, Pl. III, fig 42, Hustedt, Pascher's *Süsswasser-Fl*, 1930 *a*, p 411, fig. 787, Venkataraman, *S I Diat*, 1939, p 355 fig. 143

Cells in girdle view linear-rectangular, with somewhat parallel sides and rounded corners Valves linear, slightly constricted in the middle, with rounded ends, 28–140 μ long, 4 μ broad Kiel punctæ 7-8 in 10 μ Transapical striæ 21-24 in 10 μ, fine

Distribution—England, Arctic Sea, Anvers, east coast of Greenland, and in the river Coom in Madras

Section Sigmoideæ (Grunow) Hustedt erw

150 *Nitzschia sigma* (Kutzing) W Smith var *indica* Karsten

(Figs 423, 424, 430 and 431)

Karsten, *Valdivian Expedn* 1907, p 400, Pl LIV, figs 11 *a* and 11 *b*; Allen and Cupp, *Plank Diat. Java Sea*, 1935, p 163, fig 120

Valves linear, slightly sigmoid in girdle view, in valve view almost straight, considerably diminished in size at the extremities and elongated, 280–312 μ long, 11 μ broad Kiel punctæ 5–6 in 10 μ.

Distribution--Indian Ocean, Java Sea

Section Nitzschiellæ (Rabenhorst) Grunow

151 *Nitzschia Closterium* (Ehrenberg) W Smith

(Figs 426, 428 and 429)

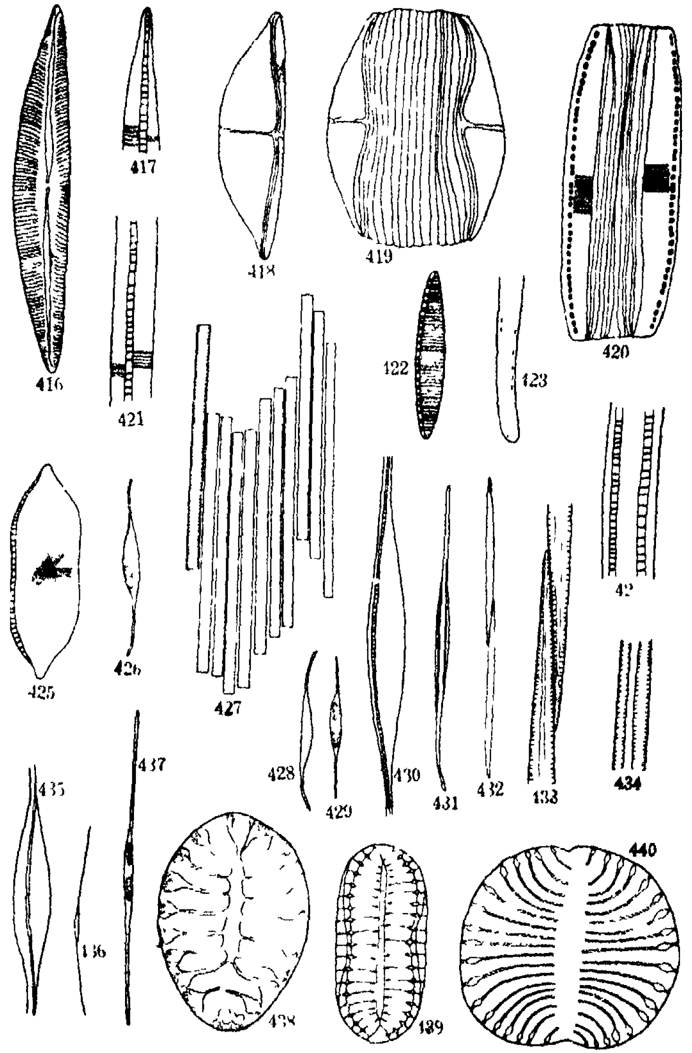
W Smith, *Syn Brit Diat*, Vol I, 1853 p 42, Pl XV, fig 120; Cleve and Grunow, *Beiträge z Kenntniss Arct Diat* 1880, p 101, Gran, *Nord Plank.*, *Bot Teil*, Bd VIII, 1908, p XIX 129 fig 172, Boyer, *Syn N Am Diat*, 1927, p 526, Lebour, *Plank Diat N Seas*, 1930, p 212, fig 176; Hustedt, Pascher's *Susswasser-Fl*, 1930 *a* p 424, fig 822, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 163 fig 122, Venkataraman, *S I Diat*, 1939, p 356, figs 132 and 133

Ceratoneis Closterium (Ehrenberg) Ralfs, Pritchard, *Hist Infusoria*, 1861, p 783, Pl XII, fig 59

Nitzschiella Closterium (Ehrenberg) Rabenhorst, *Fl Eu Alg*, pt I, 1864, p 163.

Nitzschia curvirostris Cleve var *Closterium* (Ehrenberg) Van Heurck, De Toni, *Syll Alg*, Vol II, 1891–94, p 548

Nitzschia longissima (Brébisson) Ralfs var *Closterium* (W Smith) Van Heurck, *Traité des Diatomées*, 1899, p 405, Pl XVII, fig 570



TEXT-FIGS 416-440 —Fig 416 *Cymbella marina* Castracane × 930 Fig 417 *Bacillaria paradoxa* Gmelin × 930 Figs 418–419 *Amphora ostrearia* Brébisson Fig 418, × 460, 419, × 428 Fig 420 *Nitzschia vitrea* Norman × 710 Fig 421 *Bacillaria paradoxa* Gmelin. Valve view, middle portion × 930 Fig 422 *Nitzschia vitrea* Norman. × 930 Figs 423–424 *Nitzschia sigma* var *indica* Karsten × 710 Fig. 425. *N panduriformis* var. Grunow × 930 Fig 426 *Nitzschia Closterium* (Ehrenberg) W Smith. × 428.

Fig. 427 ***Bacillaria paradoxa*** **Gmelin ×328 Figs 428–429** ***Nitzschia Closterium*** **(Ehrenberg) W Smith × 428 Figs 430 431** ***N sigma*** **var** ***indica*** **Karsten × 150 Figs 432–434** ***N seriata*** **Cleve Fig 432, × 220, 433, × 930, 434, × 930 Figs 435 437** ***N longissima*** **(Brébisson) Ralfs Fig 435, × 930 436, × 53, 437, × 428 Fig 438** ***Surirella fluminensis*** **Grunow ×710 Fig 439** ***S eximia*** **Greville × 328 Fig 440** ***Campylodiscus Iyengarii*** **sp nov ×460**

Cells living free, motile Valves spindle-shaped in the middle, ends extended into long beaks usually slightly bent or curved in opposite directions, 35–154μ long, 3 5–7μ broad Striation not visible

Distribution.—Ubiquitous along the coasts, Davis Strait, England, Scotland, Norway, Sweden, Denmark, California, Java Sea, and brackish water in Madras

152. *Nitzschia longissima* (Brébisson) Ralfs

(Figs 435-437)

Cleve and Grunow, *Beiträge z Kenntniss Arct Diat*, 1880, p 100, De Toni, *Syll Alg*, Vol II, 1891-94 p 547, Van Heurck, *Traité des Diatomées*, 1899, p. 404, Pl XVII, fig 568, Boyer, *Syn N Am. Diat*, 1927, p. 526, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 163, fig 121

Nitzschia birostrata W Smith *Syn Brit Diat*, Vol I, 1853, p 42, Pl. XIV, fig 119

Ceratoneis longissima (Brébisson) Ralfs, Pritchard, *Hist Infusoria*, 1861, p 783.

Nitzschiella longissima (Brébisson) Rabenhorst, *Fl Eu. Alg*, pt I, 1864, p. 164

Cells living singly, motile, 89-560μ long and 3 5–5 5μ broad. Central enlarged portion lanceolate Ends hair-like, elongated, nearly straight Keel punctæ 12 in 10μ Striæ not recognisable

Distribution—England, France, Denmark, Virgin Islands, Shark River, New Jersey, Pacific coast of America, Java Sea

153 *Nitzschia seriata* Cleve

(Figs 432-434)

De Toni, *Syll Alg*, Vol II, 1891–94, p 501, Gran, *Nord Plank*, *Bot. Teil*, Bd VIII, 1908, p XIX 129, fig. 174, Boyer, *Syn N Am Diat*, 1927, p 526, Lebour, *Plank Diat N Seas*, 1930, p. 213, fig 178, Allen and Cupp, *Plank Diat Java Sea*, 1935, p 164, fig. 124

Cells spindle-shaped with more or less pointed ends, 50–131 μ long and 3 5–5 μ broad, forming long chains, the ends of cells lying adpressed to each other for a short distance Striæ 12 in 10 μ

Distribution —Davis Strait, England, Scotland, Holland, Belgium, Germany, Norway, Sweden, Denmark, Atlantic and Pacific coasts of America and Java sea.

Family SURIRELLACEÆ

Sub-family Surirelloideæ

LXIII Genus *Surirella* Turpin

154 *Surirella fluminensis* Grunow

(Fig 438)

Allen and Cupp, *Plank Diat Java Sea*, 1935, p 164, fig 126

Surirava flumensis Grunow, Rabenhorst, *Fl Eu Alg*, pt I, 1864, p. 58, De Toni, *Syll Alg*, Vol II, 1891-94, p 587

Valve ovate, 50 μ long and 35 μ broad Ribs or canalculi few, about 10, inflated towards the margin, reaching narrow median canal (except last pair) Median canal not clearly recognisable Marginal striæ 24 in 10 μ.

Distribution —Adriatic Sea and Java sea

155 *Surirella eximia* Greville

(Fig 439)

Greville, *Descrip Diat West Ind*, 1857, p 10, Pl. III, fig. 6.

Surirava eximia (Greville) De Toni, *Syll Alg*, Vol II, 1891–94, p. 585.

Valve linear-oblong, rounded at the ends, very slightly constricted in the middle, 95 μ long, 43 μ broad Canaliculi delicate, about 19 on each side reaching the narrow, linear, transversely striated median space, which is attenuated towads the ends.

Distribution —West Indies.

Sub-family Compylodiscoideæ

LXIV Genus *Campylodiscus* Ehrenberg

156 *Campylodiscus Iyengarii* sp nov.

(Fig. 440)

Cells in valve view orange shaped in outline, 64 μ (short axis) and 74 μ (long axis) in diameter Rays curved, in lines radiating from a lanceolate median space, rays 4 in 10 μ

This diatom shows a resemblance to *Campylodiscus Ralfsii* W. Smith (1853, p 30, Pl XXX, fig 257, *cf* also Gregory, 1857*b*, p. 502, Pl XI, fig 52) in structure but the valvar plane in *C Ralfsii* W Smith is not bilaterally symmetrical as regards its structure in the present diatom whereas the structure on the valve—the rays, are arranged symmetrically on either side of the central space It shows a resemblance to *C angularis* Gregory (*cf.* Gemeinhardt, 1935, Pl. XVI, fig 208) but this form is more or less circular in outline, with elliptical middle space and larger number of canaliculi Again, it shows a resemblance to *C biangulatus* Greville (1862, p 20, Pl III, fig. 2) as regards the structure but this form has a circular outline with a broadly linear smooth median space, whereas the present form is orange-shaped in outline with a lanceolate median space

Distribution—Plankton of the Madras coast

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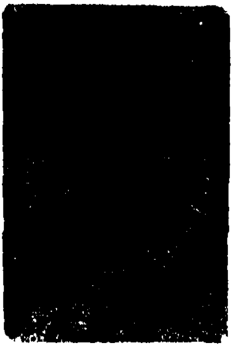
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Figs 1 and 2 *Biddulphia mobiliensis* Auxospore-formation Fig 1 Protoplast come out of the valve Fig 2 One new valve secreted in the auxospore 410

Fig 3 *Chaetoceros Lauderi* Resting spores 410

Fig 4 *Asteromphalus Wyvillei* 615

Fig 5 *Triceratium favus* 615

Fig 6 *Auliscus sculptus* 820

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ON DECAY OF CERTAIN FRUITS IN STORAGE

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Introduction

The study of storage disorders of fruits due to certain fungi has received a good deal of attention in countries outside India, but contributions from here are only a few and relate, so far the author's information goes, to plantains (Dastur, 1916) and oranges (Ghatak, 1938) only. The lack of this kind of work in this country is chiefly due to the insignificant export and the inability of the dealers to recognise the utility of application of scientific methods in fruit industry, which still remains much undeveloped although it has received a good deal of impetus quite recently But with the prospect of increased requirements and demands the problem of storing and transiting fruits is likely to become as important here as elsewhere. As is already known from the works in other countries, the fungal organisms are major causes of disorders both in storage and transit. With this view the present work has been started to find out the fungi causing the decay of fruits under local storage conditions, since in any attempt to adopt control measures the causal organisms and the sources of infection must be known beforehand. The present study deals with the storage disorders in certain Lucknow shops and other places of local storage. The investigation covers several kinds of fruits, namely mangoes, apples, pears, peaches, oranges, pomegranates and grapes. Mango has been given more attention as it forms the staple fruit of the United Provinces. The suspected sources of infection, namely the surface of the fruits, the atmosphere of storage places and mango orchards and the early infections known as 'latent infections' have been tested, in the light of previous information, under the much different storage conditions prevailing here.

Experimental

Isolation of Fungi.—Samples of fruits were brought to the laboratory in separate sterile containers from the local storage and market places. These samples were obtained at intervals of fifteen days during two fruit seasons (1937 and 1938).

In order to find out the organisms occurring on the surface of both diseased and healthy fruits, every fruit was given three separate washings in succession with sterile distilled water The whole quantity of each successive washing was separately mixed with a given quantity of standard medium and poured in plates which were then incubated at room temperature (about 30° C.) It was observed that in the culture plate of the first washing too many fungal colonies appeared close to one another, and for this reason in subsequent operations, the first washing was diluted with sterile distilled water and small quantities of this was mixed with the given amount of standard medium. The plates were examined on the third day and the fungi appearing were isolated and subcultured in tubes Only one examination of each plate was made in order that the result may not be vitiated by the contaminations occurring during the examination

The washed fruits were then utilised for isolating the fungi present in the tissues The diseased ones were used for finding out the organisms causing the decay and the apparently healthy ones for detecting 'latent infections' In each case the fruits were surface sterilised by keeping them in a saturated solution of borax for about half an hour and later in 0 1 % mercuric chloride solution for two to five minutes according to the nature of the fruits, and finally washing with sterile distilled water several times Small pieces of the fruits were cut out rapidly with a sterile knife and placed in petridishes containing the standard medium In the case of decayed fruits the pieces were taken from the parts showing spots, badly rotted areas and apparently unaffected portions In the case of 'latent infections' the organisms have been isolated from apparently healthy fruits in storage In each case quite a number of fruits and at different times of the season were used and the organisms were obtained from most of them. In the case of mangoes, fruits of different ages both from the mango orchards and storage places were tested The term 'latent infections' has been used rather in an extended sense than employed by Baker and Wardlaw (1937).

To find out the fungi occurring in the atmosphere of shops and mango orchards, petridishes containing nutrient medium were exposed to the respective atmospheres for two minutes at different times of the season. The exposed plates were brought back to the laboratory and after incubation for three days the fungi obtained were subcultured from the developing colonies The entire operation was done under aseptic conditions.

Pure cultures of the isolated fungi were obtained by using monohyphal tip or single spore culture methods

The fungi which sporulated have been identified. Some which did not produce spores have been provisionally eliminated from the text, but their cultures have been retained. Most of the fungi were identified by the author at the Imperial Agricultural Research Institute, New Delhi, and the rest at the University of Lucknow Confirmation of the specific identification, in some cases, from the respective authorities could not be obtained due to the war conditions Description, spore measurements, camera-lucida drawings, etc. of the organisms obtained are not being included here for the sake of brevity.

A list of the fungi isolated from the various sources is given in Table I.

TABLE I

Table showing a list of fungi obtained from the various sources

Type of Fruit	Fungi Isolated	Source of Isolations: Tissues of Diseased Fruits	Source of Isolations: Latent Infections	Source of Isolations: Surface of Diseased Fruits	Source of Isolations: Atmosphere of Storage Places
Mango	*Aspergillus niger* van Tiegh.	+	−	+	+
	Aspergillus nidulans (Eidam) Wint	+	+	+	+
	Aspergillus fumigatus Fresinius	−	−	+	+
	Aspergillus varsecolour (Berke Br) Thom and Raper	+	−	−	−
	Alternaria sp (Al 1)	−	−	+	−
	Alternaria sp. (Al 2)	−	−	−	+
	Acrothecium penniseti Mitra	+	−	−	+
	Colletotrichum capsici (Syd.) comb nov	+	+	−	−
	Penicillium fellutanum Biourge	−	−	−	+
Apple	*Aspergillus niger* Van Tiegh	−	−	+	+
	Aspergillus fumigatus Fresinius ✓	+	−	+	+
	Aspergillus candidus Link ✓	+	−	−	−
	Acrothecium penniseti Mitra	+	−	−	+
	Alternaria sp. (Al 1)	+	−	−	+
	Colletotrichum sp.	+	+	−	−
	Fusarium sp. (F 1)	+	−	+	−
	Rhizopus arrhizus Fisher	−	−	+	+
Pear	*Penicillium atramentosum* Thom	+	−	+	+
	Aspergillus tamarii Kita	-	−	+	+
	Aspergillus niger Van Tiegh	+	−	+	+
	Aspergillus fumigatus Fresinius	+	−	−	+
Peach	*Aspergillus niger* Van Tiegh.	−	−	+	+
	Alternaria sp. (Al 2)	+	−	−	+
	Rhizopus arrhizus Fischer	+	−	−	+
Orange	*Aspergillus fumigatus* Fresinius	+	+	+	+
	Aspergillus niger Van Tiegh.	+	−	+	+
	Alternaria sp. (Al 2)	−	−	−	+
	Penicillium fellutanum Biourage	−	+	+	+
	Rhizopus sp	+	−	−	−
	Fusarium (F 2)	+	−	−	+
Pomegranate	*Aspergillus niger* Van Tiegh	+	−	+	+
	Aspergillus fumigatus Fresinius	+	−	−	+
	Penicillium atramentosum Thom	+	−	−	+
Grape	*Alternaria* sp. (Al. 1)	+	−	−	−
	Rhizopus arrhizus Fisher	+	+	+	+

Infection Experiments.—The pathogenicity of the fungi isolated from the fruits in surface washings, in decayed tissues and as 'latent infections' was tested by inoculating mature healthy fruits with the respective fungus strains The fruits were surface sterilised by means of rectified spirit ard small punctures were made in them with a sterile needle Small portions of agar cultures of the fungi were inoculated in the punctures which were subsequently sealed off with a mixture of paraffin and vaseline Eight fruits were employed for each organism and an equal number similarly punctured and sealed but uninoculated were kept as controls. The fruits were wrapped in sterilised paper and kept at room temperature All the fungi proved to be pathogens.

A preliminary experiment was also made to find out the stage of maturity of the mango fruits at which they were susceptible to infection by various pathogens Mango fruits on the tree at various stages of maturity were inoculated by the method evolved by Granger and Horne (1924) for apples. Five fungi, all isolated from apparently healthy ard decaying mangoes, were utilised in the experiment For each fungus eight fruits were used The results of the experiment are shown in Table II in which the fungi have been arranged in the order of their activity.

TABLE II

Table showing results of inoculation experiments on mangoes

Mangoes		**Fungi Inoculated**				
Date	**Mean weight of fruit**	*Aspergillus niger*	*Aspergillus nidulans*	*Aspergillus variecolour*	*Acrothecium penniseti*	*Colletotrichum capsici*
9-5-1939 ..	76·34 gm	+	–	–	–	–
21-5-1939 ..	90·12	+	–	–	–	–
5-6-1939 ..	101·74	+	+	–	–	–
18-6-1939 ..	115·60	+	+	–	–	–
2-7-1939 ..	121·62	+	+	+	–	–
16-7-1939 ..	125·54	+	+	+	+	+
Ripe mangoes		+	+	+	+	+

The results of experiments embodied in Table II present interesting features. It will be seen that mango fruits are resistant to certain fungi up to certain stages of maturity of the fruits, after which the latter become susceptible to infection It will also be observed that the organisms considered can be arranged in the order of their infectivity in respect to the state of maturity of the fruit. *Aspergillus niger* capable of attacking fruits of all ages comes first in the order followed by *Aspergillus nidulans*. *Asper-*

gillus variecolour stands next. *Acrothecium penniseti* and *Colletotrichum capsci* are more or less of equal virulence and occupy a lower position, attacking only the slightly ripe mangoes.

DISCUSSION

Fungi obtained from the fruits.—The results of investigation embodied in this paper reveal that a number of fungi have been obtained from the fruits stored in shops On comparing the isolates from the surface and the tissues of diseased fruits, it is evident that *Aspergillus niger, Aspergillus fumigatus, Aspergillus nidulans, Penicillium atramentosum, Fusarium* sp. (F1), and *Rhizopus arrhizus* isolated from the decayed tissues, have also in many cases been found to occur on the surface, but there are still others which are present only in the tissues or on the surface of fruits. *Aspergillus tamarii* and *Penicillium fellutanum* occur exclusively on the surface while *Acrothecium penniseti, Alternaria* sp. (Al 2), *Aspergillus candidus, Aspergillus variecolour, Colletotrichum capsci, Colletotrichum* sp , *Fusarium* sp. (F2), and *Rhizopus* sp have been obtained exclusively from the tissues of decayed fruits.

A correlation also exists between the organisms obtained from shop and mango orchard atmospheres, and those obtained from the fruits diseased or apparently healthy; for example *Aspergillus niger, Aspergillus fumigatus, Aspergillus tamarii, Aspergillus nidulans, Penicillium fellutanum, Penicillium atramentosum,* and *Rhizopus arrhizus* obtained from surface washings of the fruits are common to the shop or mango orchard atmosphere, as also many of the organisms yielded from the diseased tissues, namely *Acrothecium penniseti, Alternaria* sp (Al 2), *Aspergillus niger, Aspergillus fumigatus, Aspergillus nidulans, Rhizopus arrhizus,* and *Penicillium atramentosum.*

Apart from the fungi obtained from the rotted fruits, a few have been isolated as 'latent infections' from the tissues of apparently healthy fruits. These are *Aspergillus nidulans* and *Colletotrichum capsci* from mangoes, *Colletotrichum* sp from apples, *Aspergillus fumigatus* and *Penicillium fellutanum* from oranges and *Rhizopus arrhizus* from grapes. A comparison of these with the organisms obtained from the diseased tissues of the respective fruits indicates a striking correspondence among them. For example, in the case of mangoes *Aspergillus nidulans* and *Colletotrichum capsci* have been obtained as 'latent infections' and the same organisms have also been isolated from the tissues of decayed fruits. This holds true for all the four types of fruits in which 'latent infections' have been obtained, except in the case of oranges where only one of the two fungi isolated is common to the diseased fruits. Another correlation appears with the organisms found in the atmosphere of shops and, in the case of mangoes, both shops and orchards. This indicates that the organisms obtained as 'latent infections' get entry into the fruit either when it is stored or while on the tree but the effects of the pathogen are only visible when the fruit is ripe

These facts suggest that most of the organisms causing the decay of fruits in storage are the same as found on the surface of the fruits, in the atmosphere of storage places or as 'latent infections' in the tissues of apparently healthy fruits.

Probable sources of Infection—It has been seen above that there is a marked correspondence between the fungi obtained from the diseased fruits and those from their surface washings and shop atmosphere It, therefore, seems evident that the fungi present in the shop atmosphere fall on the surface of fruits, grow and cause decay while the fruits are stored. The fungi falling on the surface of fruits probably obtain entry into the host tissue through wounds caused during the process of picking, packing and transit, as suggested by several workers, or through lenticels, as reported by Kidd and Beaumont (1925) and Baker and Heald (1932) for apples A correspondence between the fungi obtained as 'latent infections' from mangoes, apples, oranges and grapes and those isolated from the respective diseased fruits has been pointed out above 'Latent infection' is therefore another source of the disease Such infections have also been reported previously by Dastur (1916) and Simmonds (1941) for plantain, Horne and Horne (1920), Bratley (1933), Wormald (1934), and Walker (1940) for apples, and Baker and Wardlaw (1937), Wardlaw, Baker and Crowdy (1939), and Baker, Crowdy and Mckee (1940) for several tropical fruits The term 'latent infection' has been used by Baker and Wardlaw (1937) and in the present paper it has been employed in the same sense in partial modification It has been suggested by them and as is also evident from the observations made here that since these organisms are obtained from apparently healthy fruits the pathogens enter the fruits at some stage of development and lie dormant in the tissues without producing any visible sign of decay, till the fruits mature and ripen offering favourable conditions for the advancement of the organisms

Pathogenicity of the organisms obtained.—Most of the fungi isolated from the respective fruits either from surface washings, decayed tissues or as latent infections are capable of producing rot of the fruits when inoculated in them. In the case of mangoes the pathogenicity tests were carried out with fruits of different stages of maturity while still on trees. It was found that the different fungi react differently with maturity of the fruit and the strains could be arranged in order of their ability to infect the fruits of different ages The pathogenicity of some of these fungi attacking mangoes in storage has been worked out and will form the subject of a later communication

SUMMARY

Seven types of fruits, namely mangoes, apples, peaches, pears, oranges pomegranates and grapes have been studied for fungal decay in storage and its relation to shop (local storage places) atmosphere and, in the case of mangoes orchard atmosphere has been elucidated Mango has received particular attention as it is the staple fruit of the United Provinces

A number of fungi have been obtained from the tissues of diseased fruits These are *Aspergillus niger, Aspergillus nidulans, Aspergillus variecolour, Aspergillus fumigatus, Aspergillus candidus, Acrothecium penniseti, Alternaria* sp , *Colletotrichum capsci, Colletotrichium* sp , *Penicillium atramentosum,* and *Rhizopus arrhizus*

A few fungi have also been isolated as 'latent infections' from apparently healthy fruits Mangoes have yielded *Aspergillus nidulans* and *Colletotrichum capsci,* apples *Colletotrichum* sp , oranges *Penicillium fellutanum* and *Aspergillus fumigatus,* and grapes *Rhizopus arrhizus*

There is a definite correlation between the fungi obtained from the fruits and those isolated from the atmosphere of storage places and the surface of diseased fruits In the case of mangoes a similar correspondence is seen with the fungi from the atmosphere of mango orchards

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DEVELOPMENTAL MORPHOLOGY IN SOME INDIAN MILLETS

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Millets belong to several fairly closely allied genera of which the most important in India are *Setaria*, *Panicum* *Pennisetum* of the tribe *Paniceæ*, and *Eleusine* of the tribe *Chlorideæ* Like wheat and barley, millets have been cultivated since times immemorial in south Europe, Egypt and Asia—particularly Afghanistan

Recent works in Gramineæ show the great difference of opinion that exists regarding grass embryology For instance now it is widely accepted that antipodals are not merely a superfluous structure, but vitally connected with the growth and development of the young gametophyte (Brink and Cooper, *Hordeum*, 1944) It is also increasingly realised that the "double fertilization" is not an end in itself but leads to important physiological changes which are responsible for proper seed development (Brink and Cooper, *Alfalfa*, 1940) With regard to the grass embryo, the modern trend represented by works of Randolph (1936), Stover (1937), Merry (1941) and Bennett (1944) is distinctly in favour of the opinion that the cell-division is irregular and that there is no consistent arrangement or zonation of cells in the young embryo This is in direct contradiction to the other view (Souges, 1924) that there is a definite arrangement and a regular sequence of cell-divisions of the fertilized egg Numerous instances of the occurrence of polyembryony in Gramineæ due to parthenogenesis have recently been recorded (Engelbert, 1940–41, Kiellander, 1941, Håkansson, 1942). But their findings seem to be mainly confined to species of *Poa*

Millets do not seem to have attracted much attention of botanists at any time Gúerin (1898) in France was one of the first to initiate embryological studies in them Others to follow him were Sussenguth (1919) in *Panicum* and Nishimura (1922) in *Setaria* In India most of the work on the subject has been done by Krishnaswamy and Rangaswami, who jointly discovered polyembryony in *Eleusine coracana* (1930) and later (1937) published their cytological findings on the same species K Rangasami besides recording the chromosome number for *Pennisetum typhoideum* has also given a fragmentary account of its morphology

The increasing importance of millets as a suitable substitute for wheat and rice—staple foods of India—warrants a more detailed study of their cytology, morphology and life-history Information from such studies will have a direct application to the development of improved strains through plant breeding With this object the present investigation was undertaken.

MATERIALS AND METHODS

The following plants furnished the material on which the investigation is based.

(1) *Setaria italicae* Beav (Fox-tail millet)
(2) *Panicum miliaceum* L (Proso-millet or broom-corm)
(3) *Pennisetum typhoideum* Rich (Pearl millet)
(4) *Eleusine coracana* Gaertn. (Finger millet)

The seeds obtained from the Millet Specialists—Government of Madras, were sown towards the beginning of June and the materials fixed when the plants were in flower towards the middle of August. Spikelets of various ages were first dipped in Carnoy's Fluid and then transferred to Nawaschin's Fluid The hairs and bristles of *Pennisetum* and *Setaria* were removed prior to fixing, as well as the glumes, palea and lemma in the case of fertilized ovules to facilitate cutting These coverings become impregnated with silica quite early in organogeny and give considerable trouble in cutting. The material was allowed to remain in Nawaschin for 24–36 hours, then washed, dehydrated, embedded in paraffin (46° C. in winter and 54° C in summer) in the usual manner, chloroform being used as the clearing agent. After embedding, sections were cut at thicknesses varying from 10μ–18μ. The older material was cut thicker in order to obtain the embryo-sac in as few sections as possible The sections were mounted serially and stained in Heidenhain's Hæmatoxylin.

GENERAL CONSIDERATIONS

Millets are annuals with erect stem, varying in height from 1–3½ ft. in *Panicum milliaceum*, to 3–8 ft in *Pennisetum typhoideum* The inflorescence is a panicle, spikate in *S italica* and *Pennisetum typhoideum* and a terminal umbel of 2 or more sessile spikes in the case of *E coracana*. The spikelets are variously arranged In *Eleusine* they are in two rows along the side of the compressed axis and in *Pennisetum* and *Setaria* they are in groups of 1–2 and 1–6, respectively, each subtended by numerous bristles, which according to Arber (1934) are sterile spikelets The spikelets are generally 2-flowered, in *Pennisetum* the lower one is staminate, upper perfect and in *Setaria* and *Panicum*, the lower sterile and upper perfect In *Eleusine* there are usually 2–5 flowers all of which are perfect The flowers are provided with 2 glumes, a lemma, palea, 2 broad cuneate lodicules in all except *Pennisetum*, 3 stamens and a smooth oval ovary, with two long styles, each terminating in a brush-like stigma In *Pennisetum* the styles are connate at the base.

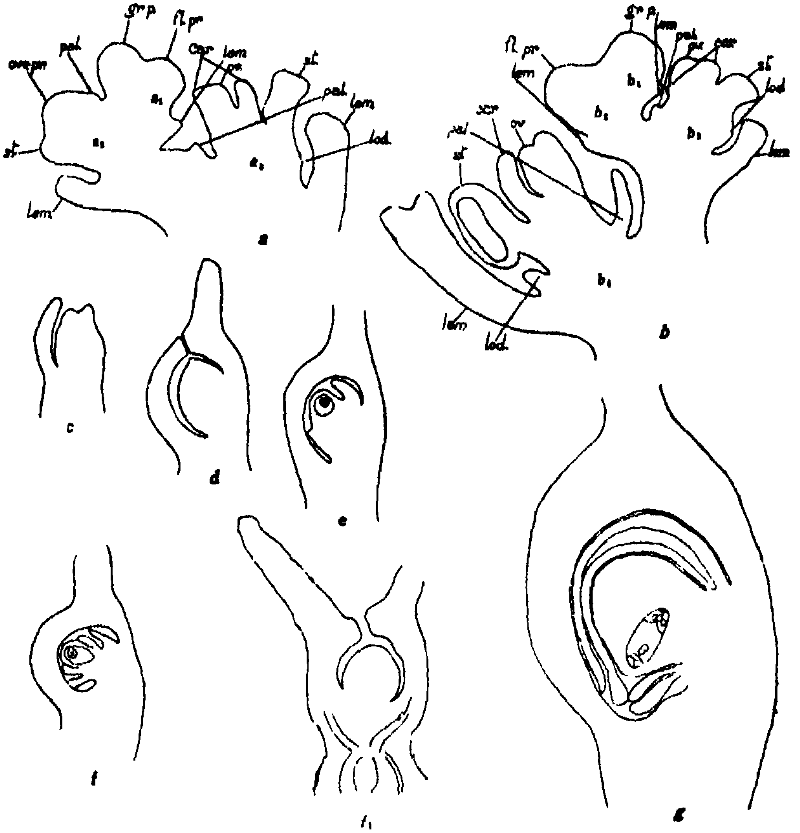
FLORAL DEVELOPMENT

The floral members arise as protruberances of the rachilla The first to make their appearance and lowest on the axis are the glumes, followed in succession by the lemma, palea and stamens appearing almost simultaneously, lodicules—differentiated from the base of the stamens and finally the ovary terminating the axis The ovary is thus the last member to be differentiated (Fig 1, *a*, *b*) In *Triticum*, Percival (1921) found that stamens appear earlier than the carpel, while palea and lodicules become distinguishable almost at the same time

The ovary is apparently simple, terminated by two styles which in the young carpel appear as conical outgrowths of its apical margins (Fig 1 *f*) The ovule at its inception is orthotropous derived from the morphological apex of the axis, but later becomes anatropous due to an one-sided growth of the latter (Fig 1 b_8). In *Eleusine* the curvature of the axis is incomplete, resulting in a campylotropous ovule (Fig 1, *g*) The origin of the ovule appears to be from the base of the carpel, but this in fact is due to the fusion of the carpel to the axis as the former grows over the latter, forming a chamber (Fig 1, *a–d*). Similar observations have been made by Percival (1921) in wheat, Anderson (1927) in *Poa pratensis* and *P compressa*, Krishnaswamy and Rangaswami (1930) in *Eleusine coracana* and others.

The ovule is invested with two integuments—the time of their appearance varying in the different millets The inner integument is differentiated almost at the same time as the ovule primordium itself in *S italica*, though in others usually after the closure of the carpels (Fig 1, *c–f*); the outer integument is formed from the base of the inner one at a later stage The inner integument is 2-layered, completely encloses the ovule and forms the micropyle, whereas the outer one is 2-layered at the top and 2 to 3 layered at the base and covers the ovule only partially. In *S italica* and *Pennisetum typhoideum* the lower end of the outer integument becomes more or less club-shaped due to cell-divisions and caps the micropyle (Fig 2) whereas in

Panicum miliaceum both the integuments go to the formation of the micropyle,—unusual in Gramineæ where an incomplete second integument is the rule.



Text-Fig 1 *a–g*—*Eleusine coracana* Development of the flower a_1, b_1, b_2—The flower primordium and appearance of lemma; a_2—Origin of stamen and palea; b_3—Differentiation of ovule, carpel and lodicules, carpel appearing as a ring of tissue at the base of the ovule, a_3—One side of the carpel fused to the ovule primordium, a_2, b_3, *c* & *d*—Development of the carpel, *d*, *e* & *f*—Development of the integument and first appearance of the archesporium, f_1—Showing the carpellary margins produced into the stylar arms (front view); *g*—Campylotropous nature of the ovule *Lem*—lemma, *pal*—palea, *st*—stamen, *ovr pr*—ovary primordium, *gr p*—growing point, *fl pr*—floral primordium, *car*—carpel, *ov*-ovule, *lod*—lodicule Figures *a–e* × 250, *f–g* × 150 Figures reduced to half their original magnifications.

DEVELOPMENT OF THE FEMALE GAMETOPHYTE

Generally the archesporial cell is differentiated shortly after the inner integument is formed (Fig 1, *d*, *e*), but in *S italica* it makes its appearance after both the integuments are formed A hypodermal apical cell of the ovule is seen to enlarge with conspicuous nucleus and denser cytoplasm than in the surrounding cells This without dividing forms the megaspore mother cell and its nucleus may possess 1-2 nucleoli As usual in Gramineæ and most Monocotyledons not more than one archesporial cell was observed in each ovule and no parietal cell is formed, though in *S italica* and *Panicum miliaceum* the epidermal cells often become 2-layered One of the apical epidermal cells in *S italica* becomes hypertrophied and prominent (Fig 3), and persists till late megasporogenesis The exact significance of this in embryogeny could not be traced but it is presumed that in some way it facilitates the passage of the pollen tube between the nucellar cells

The m m c elongates considerably before division, in *Pennisetum typhoideum* it may be thrice its original length before the nucleus even reaches prophase,—appearing like a long narrow, non-vacuolated cell slightly dilated towards the top where the nucleus is situated The division of the m.m c usually commences about the time of tetrad formation in the microsporangium. The cell divides in the usual way forming a linear tetrad of four cells (Figs 4-7) the common form in Gramineæ, though Guignard (1882) reports only two megaspores in *Cornucopiæ* The upper three cells degenerate forming a more or less T-shaped mass, due to the micropylar megaspore being tangentially flattened by the pressure of the growing embryo-sac mother-cell (Fig 8). By this time the micropylar nucellus is usually 2-layered The first division of the e m c results in a 2-nucleate embryo-sac, the nuclei migrate to the two poles and 1-2 large vacuoles are formed between them Some cells adjoining the embryo-sac degenerate, providing a nutrition layer around it The second division, simultaneous at both poles, and mostly parallel to the first one (Fig 9) gives rise to four nuclei No cell wall is formed after either of the divisions—Cooper (1937), however records in *Euchlæna mexicana* and *Zea mays* the formation of walls immediately after the second division The third division gives rise to an 8-nucleate embryo-sac. *S italica* is characterised by the presence of a large vacuole at the chalazal end as well, between the nuclei and the wall (Fig. 10); this vacuole incidentally is found persisting even in the antipodal cell cut off from that end. One nucleus from each pole migrates towards the centre to form the polar fusion nucleus, and the rest organized into the egg-apparatus and the antipodal complex (Fig 11), though in *S. italica* no wall formation in the antipodal region may take place till a later period (Fig. 12). Schnarf (1931) describes two types of embryo-sacs in the grasses, straight ones lying in the same plane as the longitudinal axis of the ovule as in *Bambusa, Oryza* and *Zea*, and others of the horizontal type, lying at right angles to the longitudinal axis as in *Festuceæ, Hordeæ, Aveneæ* and others. In millets the embryo-sacs are of the former type The size of the embryo-sacs varies—largest being found in *Panicum miliaceum* (115 9 × 34·2μ) and the smallest in *E. coracana* (74·5 × 18μ), as shown in the table below

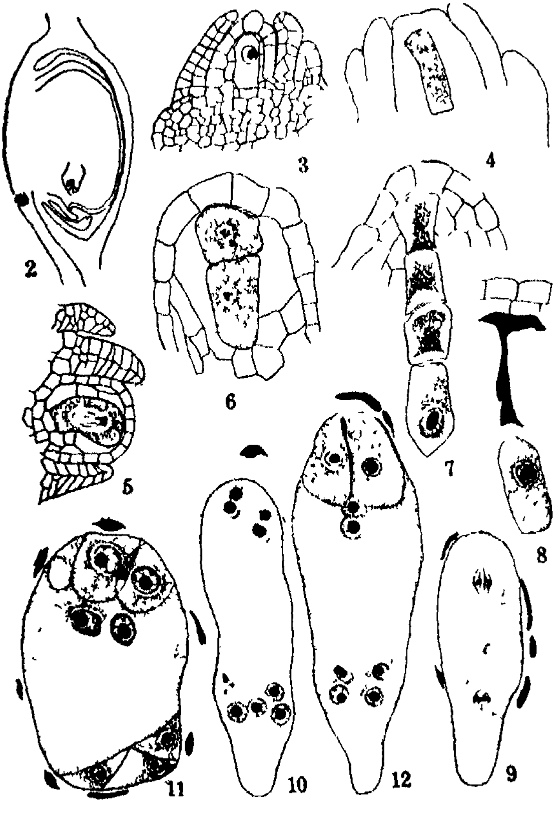
TABLE I

Illustrates the dimensions of the embryo-sacs and their components (in microns)

	Panicum miliaceum	*S italica*	*Pennisetum typhoideum*	*E coracana*
Embryo sac	115 9 × 34 2	88 3 × 33 5	86·4 × 27·2	74·5 × 18
Egg .	25 2 × 16 9	25 2 × 14·4	28·8 × 14 8	18 5 × 16 8
Egg nucleus ..	7 9	6 8	9 0	7 2
Synergid .	22 4 × 12 6	20·5 × 10 8	18 7 × 7 9	14·4 × 9·0
Synergid nucleus .	5 8	5 4	5 8	7 2
Antipodals .	27 0 × 16 2	24 8 × 15 1	31 3 × 21 6	25·2 × 12 6
Antipodal nucleus .	6 8	3 9	7 9	6·8
Polar nucleus	14 0	6 1	11·5	12·2

The egg apparatus is typical The synergids are pyriform to almost triangular in *Panicum miliaceum*, with vacuoles generally at the lower end and nuclei more or less towards the centre (Fig. 12, 13, 14) The "filiform apparatus" described by Schact (1850) and observed by Krishnaswamy and Rangaswami (1937) in *E coracana* was not observed, though in *S. italica* some synergids bear hyaline striations towards their inner walls (Fig 15) The micropylar ends of the synergids may either be broad or slightly beaked (Figs 11, 12) The lower ends in *S italica* often become pointed and somewhat hooked and not infrequently attenuated late in embryo-sac development (Fig 15)

The egg cell is slightly larger than the synergids and lies between them. In *Pennisetum typhoideum* it is bigger than in the others and may be about 1·5 times the size of the synergids It may have either a narrow or a broad basal attachment and is provided with a large vacuole at the upper and in some cases at the lower end as well. The nucleus is centrally placed and is slightly larger than the synergid nuclei (Figs 12 and 16). Later the egg elongates considerably beyond the other two cells. A heavy deposit of starch is observed even before fertilization around the egg nucleus, the pericarp region and in some cases in the antipodals as well. Occurrence of similar grains has been observed by Cooper (1937) in *Zea mays*



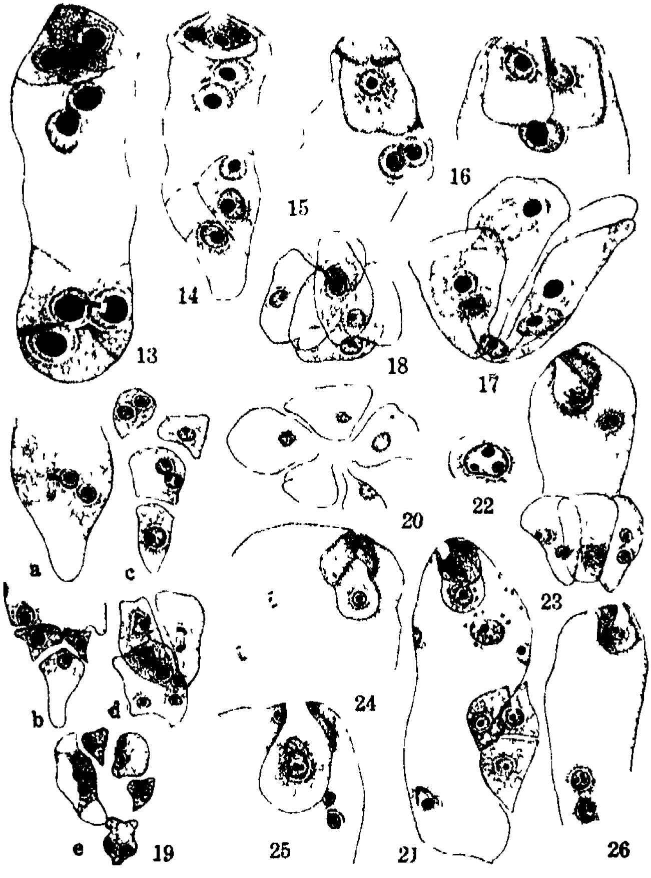
TEXT-FIGS —2 12 Figs —2, 3, 8, 9, 10 & 12—*Setaria italica* Fig 4 *Panicum miliaceum* Figs 5, 6 & 7 *Eleusine coracana* Fig 11 *Pennisetum typhoideum* Fig 2 Nature of integuments, outer incomplete, lower half forming a pad over the micropyle × 150 Fig 3 Showing megaspore mother cell with the apical epidermal cell enlarged × 550 Fig 4 Part of the ovule showing m m c nucleus at metaphase × 450 Fig 5 M m c nucleus at telophase × 550 Fig. 6 Dyad of megaspores, the nuclei in the process of second division × 800 Fig 7 Linear tetrad of megaspores × 800 Fig. 8 Functional megaspore with three degenerated megaspores forming a T-shaped mass, the epidermal nucellus 2-layered × 1,100 Fig 9 Embryo-sac nuclei at second metaphase with vacuoles in the centre and chalazal end, nucellar cells degenerated to form a nutrition layer round the sac × 1,100 Fig 10. 8-nucleate embryo-sac × 1,100 Fig 11 Young embryo-sac with full complement × 800 Fig. 12. Mature embryo-sac × 800 Figures reduced to half their original magnifications.

The two polar nuclei are the largest in the embryo-sac (compare Table I). They usually lie in close proximity of the egg cell, in which position they fuse.

Almost the first to be differentiated and the most prominent feature of the embryo-sacs are the antipodals They possess the largest cells in the sac Early in embryo-sac development, in all except *Eleusine*, the three antipodals commence division to form a tissue of usually 3-6 cells with 1-5 nuclei in each, the number and form varying with each of the four plants. In *Panicum* the usual form is for all the three cells to divide once forming a tissue of 6 cells with one nucleus in each, but quite frequently only two of the cells might divide, thus forming a 5-celled antipodal complex in which four of the cells are uninucleate and one cell binucleate (Figs 17, 18). In no case, however, more than six nuclei were observed. In *Setaria* there are usually 3-5 cells with 1-4 nuclei in each, though not more than ten nuclei were observed in any case (Fig 19 *a-e*) A large number of nuclei are usually associated with the antipodals of *Pennisetum*—as many as 23 being counted in some cases, though the number of cells are never more than six In all the three plants, however, with the maturation of the embryo-sac the antipodal cells enlarge, their contents become vacuolated and the cytoplasm starts aggregating around the coalescing nuclei (Fig 20) With the formation of the zygote, the nucellar tissue adjoining antipodals disintegrates till a passage is established to the chalaza Later the whole structure is crowded out with the growth of the endosperm In *Eleusine*, a very different type of antipodals was met with In this, the 3 cells enlarge considerably without dividing, form a dense cytoplasm and the nuclei become large and prominent, often dividing into two in each cell With the development of the endosperm, the cells are pushed to one side (towards which the funiculus is situated), but remain active till late in embryogeny (Figs 13 21) Cooper and Brink (1944) also found antipodals being similarly pushed towards the funicular side by the growing endosperm in *Hordeum jubatum*, thus indicating the important role played by them in the nutrition of the gametophyte and the young embryo

FERTILIZATION

Fertilization is porogamous One of the pollen tubes enters through the micropyle, between the integuments and nucellar cells and was seen to lie close to the egg The actual discharge of the sperms was not observed in any case, though the male nucleus was observed in close proximity to the egg nucleus in quite a number of instances. One of the synergids is disorganised with the entry of the pollen tube and the other is often found intact even after fertilization (Figs 23, 24, 25) In *Zea mays* the pollen tube



TEXT-FIGS 13–26 Figs 13, 21 *Eleusine coracana* Figs 14, 15, 16, 18, 23, 25—*Panicum miliaceum* Figs 15, 19—*Setaria italica* Figs 20, 22, 24, 26—*Pennisetum typhoideum* Fig 13 Mature embryo-sac × 2,000 Fig 14 Embryo-sac before division of the antipodal cells × 550 Fig. 15 Egg apparatus prior to fertilization Synergids with hyaline striations on their inner walls and lower outer ends hooked, eggs considerably enlarged with starch grains, the polar nuclei prior to fusion × 1,100 Fig 16 Egg, synergid and the fused polar nuclei × 550. Fig 17 Antipodal complex 5 cells, 4 uninucleate and 1 binucleate × 550 Fig 18 Transverse view of antipodals × 550 Fig 19 *a e* Various stages in the development of the antipodal cells × 1,100 Fig 20 Transverse view of antipodals showing greatly vacuolated cells with nuclei in a degenerating state × 350 Fig 21 Post-fertilization stage, the active and undivided antipodal cells pushed to one side by the growing endosperm, deposit of starch grains near the egg × 450 Fig 22 Triple fusion nucleus × 700 Fig 23 Post-fertilization stage × 350 Fig. 24. Post-fertilization stage—formation of endosperm × 700 Fig 25 Male gamete inside the egg nucleus × 550 Fig 26 Showing the multiple number of nucleoli in the initial endosperm nucleus × 700. Figures reduced to ½ their original magnifications.

enters between the synergids, so that neither of them is disorganised (Cooper, 1937), in *Festuca, Anthoxanthum, Coleanthus* and *Bambusa* the synergids are destroyed before fertilization (Schnarf, 1931) In *Eleusine,* Krishnaswamy and Rangaswami (1931) record the occurrence of fertilization 6 hours after pollination, Taradau (1927-28) in *Oryza*—after 12 hours, and Percival in *Triticum* after 30-40 hours The male nucleus as far as could be determined appeared spherical to oval and not vermiform as in wheat (Percival). Sterile embryo-sacs, in a degenerating state were found in abundance both in *Panicum* and *Eleusine*

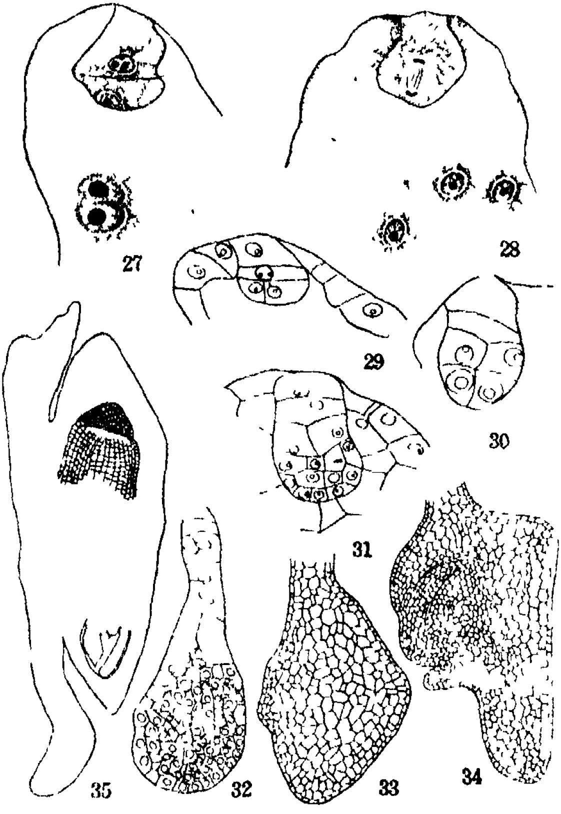
ENDOSPERM

Triple fusion, first observed by Nawaschin (1898) and now considered to be of general occurrence was observed in *Pennisetum* when all the nuclei were seen fusing together (Fig 22) The primary endosperm nucleus divides soon after fertilization and sometimes even before fertilization is complete, apparently without undergoing any rest Numerous nuclei are formed interconnected by cytoplasmic strands and lying at first peripherally and then filling up the whole sac cavity The changes in the egg are comparatively slow, 40-50 endosperm nuclei being formed before even the first division of the zygote takes place Cell wall formation commences near the embryo when it is from 4-8 celled, cells cut out being uninucleate with 1-3 nucleoli in each. Quite frequently in *Panicum* and *Pennisetum,* the primary endosperm nucleus forms numerous nucleoli before it starts dividing (Figs 23, 26); later these nuclei are seen in various stages of fusion (Fig 25). The parietal layer of cells gradually encroaches towards the centre, completely obliterating the cavity Gordon (1922) found that in the formation of the endosperm of wheat, barley and oats,—" the lining layer of the embryo-sac assumes the character of cambium, which produces segment cells only on its inner surface " There is no parietal tissue formation in any of the millets under consideration Storage with starch begins when the endosperm is completely formed and first of the starch appears at the end furthest from the embryo but in course of time all the cells are packed, except the surface aleurone layer.

EMBRYO

The egg after fertilization undergoes a long period of rest and then divides It is very rare for the fertilized egg to divide before the primary endosperm nucleus, but this was noted in some *Pennisetum* preparations, where a 2-celled embryo had already formed, while the polar nuclei had not even fused (Fig 27) This is probably due to failure of triple fusion, as the male nucleus was nowhere to be observed.

The first division of the zygote is at right angle to its longitudinal axis—thus dividing it transversely into two cells. The apical cell then divides transversely once forming two cells, both of which divide vertically to form 4 cells. These four cells form the initial embryo (Figs 28, 29, 30) Growth and further divisions in all directions soon produces a central core of cells enclosed in a well marked epidermis (Fig 31) The basal cell in the meantime divides to form the multicellular suspensor, though a feebly developed



TEXT-FIGS—27-35 Figs 27–34 *Pennisetum typhoideum* Fig 35 *Setaria italica* Fig. 27 Pro embryo of 2 cells, endosperm not formed × 700 Fig 28 First division of the zygote × 700 Figs 29–34 Different stages of the development of the embryo, explanation in text Fig 29 × 400, Fig 30 × 700 Figs 31–33 × 400 Fig 34 × 250 Fig 35 Embryo × 150 Figures reduced to ½ their original magnifications suspensor is the common rule in Gramineæ. In *Avena fatua* the suspensor consists only of the primary basal cell (Cannon, 1900) The pro-embryo at this stage appears as a club-shaped body with a narrow elongated base Above the apex on the side opposite the endosperm a protuberance forms (Fig 32) The distal portion of the embryo below this protuberance develops as the scutellum The coleoptile appears as a ring of tissue, which grows over this protuberance or the stem-apex (Fig. 33) As the lower half of the ring grows more rapidly than the upper, it appears as a prominent scale in longitudinal section (Fig 34) No epiblast was observed in any of the embryos. Meanwhile the mass of tissue constituting the upper end of the embryo, commences to divide and so differentiates the root Owing to unequal growth a split forms in the tissue, separating the basal ground tissue from the root initial By further growth this cavity enlarges so that on maturity the upper portion of the ground tissue appears as a sheath—the coleorhiza—enclosing the root proper (Fig 35) This agrees with Percival's findings on wheat No cases of polyembryony were observed

INTEGUMENT AND PERICARP

The development of the integuments in millets is similar to that recorded for wheat, rice and maize Of the two integuments, the outer is shorter and degenerates after some time, leaving the inner one to form the seed coat. In *Panicum*, however, both the integuments are complete and the tip of the outer one becomes multicellular with the growth of the embryo-sac In *Eleusine* with fertilization of the egg, the outer integument starts disorganizing, and the cells of the inner integument show an enlargement in size; the growth is more prominent in the inner layer, particularly at the micropylar end and it commences from the chalazal region With the formation of the embryo, brown deposits probably tannin (Harrington, 1923) appear —the outer cell layer of the inner integument taking no part in this and collapsing after some time The grain in *Eleusine* is an utricle, the pericarp coming off as a thin whitish covering with threshing (Krishnaswamy and Rangaswami, 1937) The pericarp development is the same as already recorded by Percival for wheat

DISCUSSION

Gynæcium —The number of carpels in Gramineæ has long been a point of controversy, but the majority trend of opinion is in favour of a monocarpellary simple ovary, though in order to put forth a feasible explanation for the presence of more than one style, the existence of two or more carpels has often been suggested According to Walker (1906) and Hector, the gynœcium of Gramineæ can be best regarded as the product of fusion of three carpels In the "Grass-type", two producing the styles or the silk and the third the ovule, *e g*, *Zea mays, Setaria italica* and others, whereas in the "Bamboo-type" all the three carpels going to the production of styles. Rangasami (1935) considers the gynœcium of *Pennisetum typhoideum* as the product of two carpels; one short and thick, producing the ovule and the other thinner one, the style In support of his statement he records the presence of two branches of vascular traces passing to the carpels Rangasami unfortunately seems to have confined his observations to only longitudinal sections taken from one side of the material showing fusion of the carpellary margins at the apex This would naturally give the impression of the presence of two carpels, only one of which would seem prolonged into the style If, however, longitudinal sections are cut from the front face, it is seen that both the ends go to the formation of the 2 styles which are slightly connate at the base (Fig. 1 f_1) It is in the transverse section of very young flowers that the true picture of the gynœcium is revealed The single carpel arises as a ring of tissue from the base of the morphological apex of the floral axis and possesses three vascular traces—a large median trace with two smaller lateral ones—similar arrangement to that found in the glumes of the flower The thicker median trace indicates the fusion of the axis to the carpel, which in longitudinal section led Rangasami to believe that the ovule originated from the carpel The number of carpels and development of the gynœcium is similar in all the four materials

Female Gametophyte —The archesporial cell generally appears shortly after the inner integument is formed, this fact holding true for *E coracana* as well, and not long after both the integuments are differentiated as stated by Krishnaswamy and Rangaswami (1937) As usual in Gramineæ the archesporial cell without dividing forms the megaspore mother cell—no parietal or covering cells being formed, *Cornucopiæ nocturnum*, however, may be quoted as an exceptional case where Guignard records the presence of covering cells. But what usually happens in the millets is that the micropylar nucellus divides by periclinal walls becoming many layered. Weatherwax (1916) in *Zea* found these epidermal cells degenerating after dividing by tangential walls What K Rangasami considers to be the parietal cell in *P typhoideum* appears to be nothing more than the nucellus formed by the division of the epidermal cell—a condition of frequent occurrence in the millets.

In this connection it is interesting to note that in all the materials though the tetrad formation is linear, the degenerating megaspores always give the impression of a T-shaped structure due to reasons already stated. No mention of this feature, however, has been made either by K. Rangasami or Rangaswami-Krishnaswamy in their studies on Indian Millets

The shape and size of the embryo-sacs varies greatly between the four genera The length of the embryo-sac may be from about 2·7 in *Setaria* to about 4 times the breadth in *Eleusine*, though usually it is about thrice the breadth. The size of the embryo-sac has very little to do with the size of the cells in the egg apparatus and antipodals Though ***Panicum*** has the largest embryo-sac (115 9 × 36 2μ), yet *Pennisetum* has the largest egg (28 8 × 14 8μ) and antipodal cells (31 3 × 21 6). This incongruity in the size of the embryo-sacs is also evident in the size of the nuclei (compare Table I) The nuclei of *Eleusine* are comparatively larger than those of any of the others, whereas those of *Setaria* appear to be the smallest The polar nuclei are the largest in the sac, about 2–3 times the size of the others; in *Panicum* it reaches a dimension of about 14 0μ

Strongly developed antipodals are characteristic not only of millets but of all Gramineæ In *Triticum* it is 6–10 celled at fertilization (Percival) though more than 38 have been observed by Köernicke (1896) after fertilization In *Zea mays* the number varies from 24–36, the largest number recorded so far being 60 for *Bambusa bamboo* Similarly well-developed antipodals have also been observed in *Oryza*, *Sorghum*, *Hordeum* and others.

Schnarf (1931) on the basis of the number of antipodals, groups the Gramineæ into three classes (i) those with only three big cells, each containing 1–a nuclei as in *Cornucopiæ nocturnum Alopecurus pratensis*, *Avena pubescens*, etc , (ii) those with only up to 10, 1–a nucleate antipodals and (iii) those with more than 12 cells as in *Avena fatua*, *Triticum*, *Oryza*, etc. Of the millets, *Eleusine* may be classed in the first of these groups and the rest in the second

The antipodal cells enlarge and divide with the maturation of the embryo-sac On the basis of this fact Brink and Cooper (1944) suggest that the activation of the antipodal nuclei and enlargement of the cells is affected by the entry of the male gamete and later by fertilization This, however, cannot be confirmed by the observations made on the millets, as quite frequently the cells enlarge and become vacuolated even prior to fertilization and later disintegrate. Similar condition prevails in *Saccharum*, where the cells degenerate prior to fertilization.

Antipodals may sometimes persist for a long period. In *Zea* and *Coix lacrima* Weatherwax (1926) found them in almost ripe seeds.

The nutritive function of the antipodals seems to have been first suggested by Hofmeister (1849) and conclusively proved by Westermaier (1890) Ikeda (1902) observed that the antipodals are nutritively active from the full maturation of the sac to the formation of endosperm, after which they gradually change their structure and weaken, during this period the antipodals serve to conduct food for the growth of the egg apparatus and endosperm formation From this fact, he divides the antipodals into two general types - passive and aggressive In passive type the antipodals remain active, often become very much enlarged and even form a mass of tissue, but they are not associated with an invasion of the chalazal region and simply receive material from it. This is the type characteristic of the Monocotyledons (except Gramineæ) In the aggressive type active and often multiplying antipodals are associated with the penetration of the chalazal region by the elongated antipodal cells The millets exhibit both the types In *Eleusine* we find the first kind and in others the second kind of antipodals

Embryo--Of the three-celled pro-embryo, Krishnaswamy and Rangaswami are of the opinion that only the terminal cell goes to the formation of the embryo proper and the rest by one or two divisions forms the suspensor. This does not appear to be the case from a close observation of the present material Both the terminal cells go to the formation of the embryo and the basal cell by a few divisions forms the suspensor

The divisions following on the first two were found to be irregular, often forming multi-nucleate cells, so that no special significance can be attached to the sequence of cell division or to the arrangement of cells in the early development of the embryo This is in agreement with the findings of Randolph (1936) in *Zea* and of Merry (1941) in *Hordeum* Differentiation of organs according to Bennett (1944) begins 60–72 hours after pollination. The clear-cut differentiation attributed to the pro-embryo of grasses by Souges (1924) in his studies on *Poa annua* cannot be corroborated by the investigation on Indian millets Neither is it possible to support Krishnaswamy and Rangaswami in their statement that the embryo of *Eleusine* shows a differentiation into epidermis, plerome and periblem

Further, Krishnaswamy and Rangaswami record the presence of epiblast in *Eleusine*, whereas this structure was not observed in any of the embryos studied It clearly appears from the illustration given by the above authors that the structure labelled as epiblast is nothing but the lower half of the coleoptile which grows more rapidly than the upper half and appears as a prominent scale in longitudinal section.

SUMMARY

1. The floral members arise as protuberances of the rachilla:—the order of succession being—glumes, lemma, palea, stamens, lodicules and gynœcium

2. The gynœcium consists of a monocarpellary ovary with a single terminal ovule and two styles

3 There are two integuments, inner forming the micropyle and the outer incomplete; both are 2-layered In *Panicum* both the integuments form the micropyle

4 The archesporium comprises of a solitary, hypodermal cell, no parietal cells being formed *Setaria* shows a peculiar hypertrophy of one of the epidermal apical cells

5. Tetrad formation is linear; lowest megaspore forms the embryo-sac mother cell

6 The mature embryo-sac is 8-nucleate and of the normal type in all the plants

7 The egg-apparatus is typical, the egg cell is slightly larger than the synergids and elongates considerably after fertilization. It has a heavy deposit of starch grains The polar nuclei are large and lie in close proximity to the egg where they fuse

8 The antipodals are well developed—the forms varying in the four plants In *Eleusine* none of the 3 cells divide but become large and prominent; in *Panicum* they form a tissue of 6 uninucleate cells; in *Setaria* there are 3–5, 1–4 nucleate cells and in *Pennisetum* there are 6 multinucleate cells *Eleusine* has the passive type and the rest the aggressive type of antipodals

9. Fertilization is porogamous and the sperm cell is spherical.

10 The primary endosperm nucleus undergoes free nuclear division without rest—wall formation commencing near the embryo first.

11 The zygote divides to form a three-celled proembryo, the two terminal ones of which divide and redivide to form the embryo and the basal one the suspensor The embryo consists of a terminal cotyledon, the coleoptile enclosing the laterally situated stem apex and the coleorhiza enclosing the radicle with its root-cap.

12 Of the two integuments, the outer one disintegrates, the inner forming the seed coat; deposits occur in the surviving coat of *Eleusine* seed. Pericarp development same as recorded for wheat

My grateful thanks are due to Dr. I. Banerji under whose personal care and guidance this work has been done

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STUDIES IN CROP PHYSIOLOGY

Deficiency-Sufficiency Effects of Fertilisers upon Growth and Protein Content of Wheat

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INTRODUCTION

IN a previous paper* the effect of sub-optimal, optimal and supra-optimal doses of nitrogen, phosphoric acid and potash, was investigated under conditions of pot culture. Specific responses under varied conditions of nutrient supply in soil were pointed out: under conditions of non-limiting phosphoric acid and potash, nitrogen was noted to improve reproductive growth more than vegetative with each successive addition of this ingredient Potash on the contrary, improved vegetative growth more than reproductive when N and P were supplied in non-limiting doses as basal dressing Phosphoric acid in sub-optimal and supra-optimal doses behaved like potash in increasing vegetative vigour; in optimal dressings it improved reproductive growth and thus in effect resembled nitrogen High yields were under all conditions of nutrition invariably associated with low height/tiller ratio. Protein content was always high in cultures well supplied with nitrogen and phosphoric acid.

While specific responses were thus recorded when each of the ingredients N, P, or K were varied only one at a time, it remained to be investigated as to how far the responses differed when one, two or three of these were simultaneously increased or decreased above or below their respective optimal doses. The present paper elucidates these effects under sand-cultural conditions.

PROCEDURE OF EXPERIMENTATION

The experiment was conducted in cement concrete pots 18 × 12" in size each filled with 30 kgm. of sand. Eight series of cultures were maintained as indicated below:—

1. *Standard fertiliser culture*: where the standard dose of N, P, and K was maintained at 60 lbs. N, 40 lbs. P_2O_5, and 30 lbs. of K_2O per acre; actual quantity added per pot was calculated on top surface area basis of pots. Nutrients were added in the form of sulphate of ammonia, superphosphate and sulphate of potash.

2. *Nitrogen deficiency-sufficiency cultures*: where P and K were maintained as in (1) and only N varied as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 2, 4 and 8 times the standard dose.
3. *Phosphorus deficiency-sufficiency cultures*: where N and K were maintained as in (1); P varied as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 2, 4, and 8 times the standard dose.
4. *Potash deficiency-sufficiency cultures*: where N and P were maintained as in (1) and only K varied as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 2, 4, and 8 times the standard dose
5. *NP deficiency-sufficiency cultures*: where K was maintained as in (1) and both N and P varied simultaneously as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 2, 4, and 8 times the respective standard doses.
6. *NK deficiency-sufficiency cultures*: where P was maintained as in (1) and both N and K varied simultaneously as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 2, 4 and 8 times the respective standard doses.
7. *PK deficiency-sufficiency cultures*: where N was maintained as in (1) and both P and K varied simultaneously as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 2, 4 and 8 times the standard doses.
8. *NPK deficiency-sufficiency cultures*: where the dose of all the three ingredients was simultaneously varied as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 2, 4 and 8 times their respective standard doses No basal dressing of any ingredient was applied.

The treatments totalled 43, and were replicated five times, thus making the total number of cultures to 43 × 5 or 215 The experiment was conducted during the cropping season of 1939–40 on wheat (var Pusa 52) Six plants per pot were allowed to grow throughout the life-cycle. Fertilisers were applied at sowing Proper care was taken regarding watering and hoeing at successive stages of the life-cycle.

Growth characters.—Five plants, one from each replication, were selected at random, and tagged early in the life-cycle for the study of the following growth characters: (i) Height of the main shoot; (ii) Number of green leaves on main shoot; (iii) Leaf length; (iv) Leaf width; (v) total number of tillers (shoots) per plant, (vi) ear-bearing tillers per plant, (vii) ear length; (viii) grain yield per pot; (ix) straw yield per pot; and (x) absolute weight of seeds. Records of these characters were maintained at one or different stages of the life-cycle Height/tiller and total tiller/ear-bearing tiller ratios were calculated on the basis of the mean life-cycle values recorded for these characters.

Nitrogen content of grain.—Analysis of grain was conducted on the composite grain sample from all replications. Composite sample of air-dry seeds was crushed in a laboratory mill; flour obtained was stored in air-tight sampling bottles till it was needed for analysis. Total nitrogen in flour was determined by Kjeldahl's method modified to include nitrate nitrogen[8]; protein nitrogen was estimated by soaking the flour in 2·5 per cent solution of trichlor-acetic acid for an hour and filtering through ashless filter-paper. After repeated washing with trichlor-acetic acid, the leached material was digested with filter-paper as in case of total nitrogen. True protein percentage was obtained by multiplying the protein nitrogen by 6·25.

EXPERIMENTAL RESULTS

A. Effects of Nitrogen upon Growth Characters and Nitrogen Content of Wheat

All growth characters were affected by the level of nitrogen supplied to the culture medium (Fig. 1, Table I). Height, leaf width, total number of

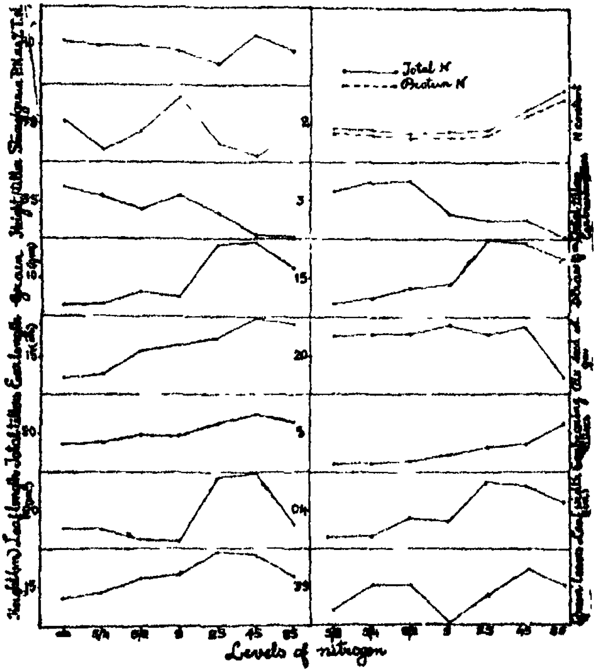

FIG. 1. Effect of increasing levels of introgen upon growth characters and nitrogen content of wheat grain.

TABLE I

Growth characters, yield, and nitrogen content of wheat under varying levels of nitrogen

Standard dose of N = 60 lbs N per acre

	Characters	S/8	S/4	S/2	S	2S	4S	8S
1	Mean height (inches) ..	13·83	14·4	16·16	16·95	19·83	19·04	18·40
2	Mean number of green leaves on main shoot	3·60	3·92	3·92	3·44	3·80	4·12	3·92
3	Mean leaf length (in.)	5·81	5·81	5·44	6·39	7·82	7·90	5·94
4.	Mean leaf width (in.)	0·33	0·34	0·38	0·37	0·47	0·46	0·42
5	Mean number of tillers ..	3·55	3·95	4·90	4·65	6·15	7·35	6·35
6.	Number of ear bearing tillers	1·0	1·0	1·2	2·0	3·0	3·60	6·20
7	Ear length (in.) ..	4·6	4·46	5·14	5·10	5·58	6·24	6·06
8	Grain yield (gm.) .	3·0	3·40	6·40	5·20	18·30	19·60	12·50
9.	Straw yield (gm.)	5·8	7·30	11·60	12·70	30·10	28·80	23·00
10	Absolute Wt. (gm.) .	3·07	3·29	3·20	3·63	3·31	3·61	1·87
11	Height/tiller ratio .	3·9	3·65	3·29	3·64	3·22	2·59	2·58
12.	Straw/grain ratio .	1·93	1·55	1·80	2·22	1·64	1·49	1·84
13	Total tiller /ear-bearing tillers	3·55	3·95	4·08	2·63	2·05	2·04	1·02
14	Total N % in grain .	1·693	1·636	1·474	1·492	1·655	2·656	3·693
15	Protein N % in grain .	1·555	1·476	1·334	1·334	1·413	2·466	3·281
16.	True Protein % ..	9·719	9·225	8·338	8·338	8·831	15·413	20·506
17	Protein N as % total nitrogen	91·849	90·220	90·502	89·410	85·378	92·845	88·848

Note —Characters *1 & 2* average of five stages (*30, 45, 60, 90* and *120* days).
" 3–5 mean of four stages (30, 45, 60 and 90 days).
" 6–7 recorded at one stage (120 days) only
" 8–10 recorded at harvest.
" 11 & 13 calculated from mean life-cycle values.
" 12 calculated from values at harvest.
" 14–17. quantitative estimation in harvested grain
C. D. at 5% for grain yield only ± 2·27.

tillers, ear-bearing tillers, ear length, grain and straw yield were higher under heavier nitrogen dressings. Supra-optimal doses of the order of 2 or 4 times the standard level were very effective in bringing about the above changes. Yields of grain and straw were maximum under these doses. Further increase in nitrogen to eight times the standard dose, though helpful in so far as ear-bearing tillers was concerned, proved to be toxic in effect. This was noticeable on all characters. Range of toxicity differed with the character; in some cases for instance, height, toxic effects of nitrogen were evident at lower levels; in others, they were evinced only under the highest dose of nitrogen tried in these investigations. Total nitrogen and protein nitrogen content of grain were increased with each successive increase in nitrogen even upto the highest supra-optimal dose.* Protein nitrogen expressed as percentage of total nitrogen, however, was not affected so much.

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* For purposes of comparison all effects are discussed relative to standard doses of 60 lbs. N, 40 lbs P_2O_5 and 30 lbs. K_2O—doses which were found optimal in the investigations of nutritional response (³).

It was curious to note that while height and tillering both increased with nitrogen application, the ratio of height/tiller showed a decrease with increasing nitrogen levels There appeared to be greater production of tillers under heavier nitrogen doses than a corresponding increase in height. The proportion of total tiller to ear-bearing tillers increased under sub-optimal dressings but definitely fell down under optimal and supra-optimal doses of nitrogen. High grain yields under heavy applications of nitrogen were thus associated with low height/tiller and low total tiller/ear-bearing tiller ratios; conversely, low yields were associated with high ratios of height/tiller and total tiller/ear-bearing tiller Straw/grain ratio on the other hand, was high under optimal doses and declined on both sides of the optimum.

B Effects of Phosphoric Acid upon Growth Characters and Nitrogen Content of Wheat

Effects of phosphoric acid under otherwise adequate supplies of nitrogen and potash were less characteristic. Increasing doses of P were helpful in improving vegetative vigour, increasing height, tillering and leaf length; this was particularly noticeable in supra-optimal dressings. Grain and straw yields were also high under these high doses In general, sub-optimal

TABLE II

Growth characters, yield and nitrogen content of wheat grain under varying levels of phosphoric acid

Standard dose of P = 40 lbs P_2O_5 per acre

Characters	S/8	S/4	S/2	S	2S	4S	8S
1. Mean height (inches)	18 24	17 54	17·74	16 93	19 96	19·35	20·10
2. Mean number of green leaves on main shoot	3 68	3 60	3 64	3 52	3·46	3·83	3·52
3 Mean leaf length (in)	6 78	6·77	7 45	6 73	8 08	7 81	7·36
4. Mean leaf width (in) .	0·46	0·38	0 40	0·38	0 43	0·40	0 44
5. Mean number of tillers ..	4·55	4 95	5 45	4 65	6·75	6·45	6·10
6. Number of ear-bearing tillers	3 0	2 2	2·0	2 0	4 2	2 6	4 0
7. Ear length (in) ..	5·36	5 52	5 32	4·1	5 62	5 44	5·30
8. Grain yield (gm.)	8 2	7 2	7·0	5 2	14·2	14 52	14 0
9. Straw yield (gm) .	15 8	15·8	12 8	12·7	27 8	23 8	27 2
10. Absolute/weight seeds .	3 18	3·38	3 82	3 63	3 39	4 09	3 20
11 Height/tiller ratio	4·0	3 59	3·25	3·64	2 95	3·0	3·3
12. Straw/grain ratio .	1 92	2 19	1 83	2·44	1 74	1·62	1·94
13. Total tillers/ear bearing tillers	1 52	2·25	2 77	2 32	1 60	2·49	1·52
14. Total N % in grain ..	1 501	1·425	1 416	1 492	1 347	1·401	1 483
15. Protein N % in grain .	1 300	1 300	1·327	1 334	1 275	1 321	1·331
16. True Protein % .	8·11	8 110	8 294	8 338	7 969	8 256	8·319
17 Protein N as % total nitrogen	86·600	91·228	93·715	89 410	94 653	94 280	89·750

Note—Refer Table I; C. D at 5% for grain yield : ± 2·68.

dressings were less useful than supra-optimal doses on majority of plant characters Leaf number remained practically unaffected; so were the effects of varying phosphoric acid supply upon total nitrogen and protein nitrogen content of the grain. Higher doses of P, however, helped in greater proportion of protein to total nitrogen (Fig 2, Table II)

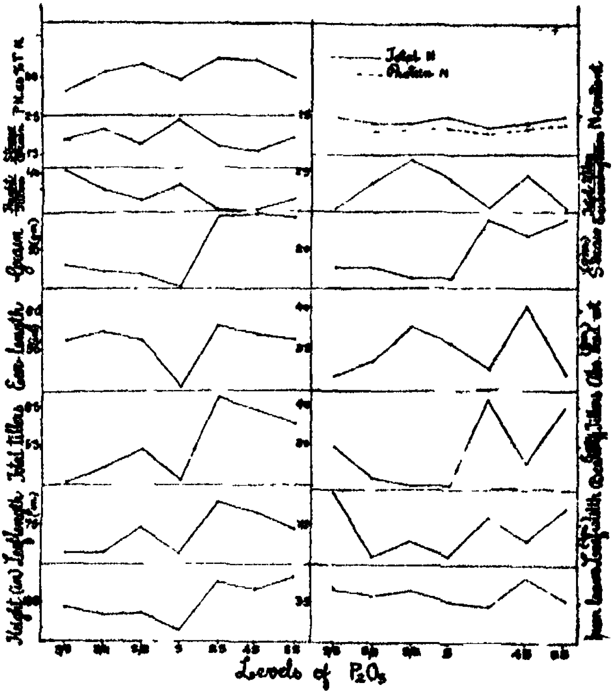

FIG. 2. Effect of varying levels of phosphoric acid upon growth characters and nitrogen content of wheat grain

Straw/grain ratio fluctuated only slightly with each successive additions of P and exhibited higher values for the standard dose. Height/tiller ratio showed a characteristic fall with increasing doses of phosphoric acid. There was a greater tendency of tillering as compared to shoot elongation under heavy doses of P. Sub-optimal doses of the order of ⅛, ¼ and ½ the standard level of phosphoric acid, showed increasing ratio of total tiller/ear-bearing tillers; supra-optimal and optimal doses with one single exception lowered it. There was a tendency of greater fertility of tillers under heavy phosphorous feeding than under lower levels of phosphorous nutrition.

C. Effects of Potash upon Growth Characters and Nitrogen Content of Grain

The effects of potash were quite contrasting in supra-optimal and sub-optimal doses. In the latter case, increasing potash resulted in low grain and straw yields, accompanied by more or less similar decline in leaf size, fertile tillers, ear length, and absolute weight of grain. Increasing potash application in the sufficiency series resulted on the contrary, in improving grain yield, straw, ear length, tillering particularly fertile tillers and leaf size (Fig. 3, Table III). Total nitrogen content of grain and protein nitrogen percentage, did not differ materially except under the highest dose when higher values were recorded. Protein nitrogen expressed as percentage of total N was, however, slightly higher under supra-optimal potash dressings. Straw/grain ratio also altered but little except under heaviest dose of potash which raised it. Increasing potash upto standard dose produced larger

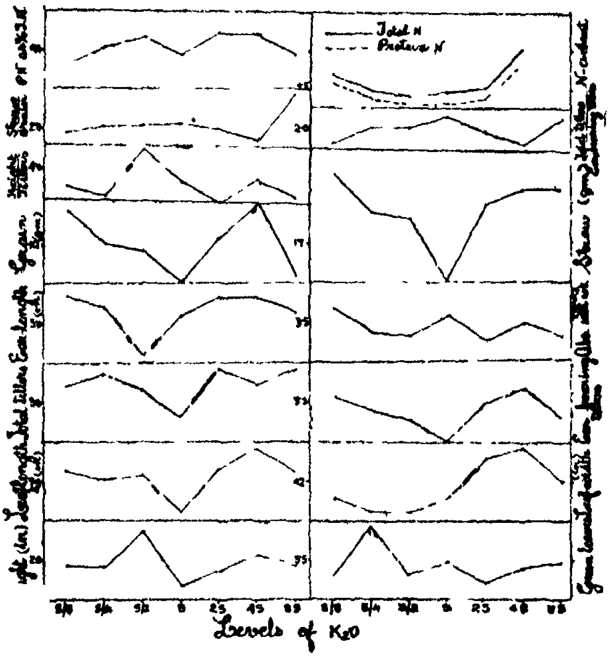

FIG. 3. Effects of increasing levels of potash upon growth characters and nitrogen content of wheat grain

TABLE III

Growth characters, yield and nitrogen content of wheat grain as affected by varying levels of potash

Standard dose of potash = 30 lbs K_2O per acre

Characters	S/8	S/4	S/2	S	2S	4S	8S
1 Mean height (inches)	19·27	19 16	23 39	16 95	18 72	20·70	19 10
2. Mean number of green leaves on main shoot	3·3	3·92	3 32	3·48	3·20	3·40	3·48
3 Mean leaf length (in) ..	7·73	7·51	7·67	6·73	7·78	8·36	7·88
4 Mean leaf width (in) .	0·40	0 38	0·38	0·40	0 45	0·46	0·42
5. Mean number of tillers .	5 40	5·70	5 30	4 65	5·95	5·55	5·95
6 Number of ear bearing tillers	3 2	2 8	2 6	2·0	3·0	3·4	2·6
7. Ear length (in) ..	5·36	5 2	4 6	5·1	5·36	5 36	5·18
8. Grain yield (gm) .	14 3	10 0	9 4	·5 2	11 0	15·52	6·4
9. Straw yield (gm) ..	26·2	21·4	20·6	12·7	22 4	24 3	24·4
10. Absolute wt of seeds .	3 71	3·42	3 38	3 63	3 31	3·53	3·39
11. Height/tiller ratio ..	3·57	3·36	4·41	3 64	3·15	3·73	3·21
12. Straw/grain ratio ..	1 83	2 14	2·19	2·25	2·04	1 56	3 81
13. Total tiller/ear bearing tillers	1 69	2 03	2 03	2·32	1·98	1·63	2·29
14. Total N % in grain .	1 501	1 501	1·444	1·492	1·405	1 309	1·444
15. Protein N % in grain ..	1·300	1·352	1 263	1 334	1·271	1·244	1·392
16 True protein % .	8 11	8 45	7 894	8·338	7·944	7·775	8·700
17. Protein N as % total nitrogen	86·609	90·073	87 465	89·410	90 462	95·034	96·390

Note—Refer Table I ; C D. at 5% for grain yield : ± 0·97.

number of shoots as compared to fertile tillers; further increases improved fertility of tillers more. Height/tiller ratio was affected less markedly.

D. *Effects of Levels of NP upon Growth Characters and Nitrogen Content of Grain*

When both nitrogen and phosphoric acid were raised simultaneously from the lowest sub-optimal to the highest supra-optimal level, the effect on growth characters and nitrogen content ~~were~~ was most characteristic (Fig. 4, Table IV). Height, leaf size, tillering, ear length, grain and straw also increased with each successive additions of these two ingredients. Absolute weight was increased only upto the standard dose and later declined under supra-optimal dressings Green leaves on the main shoot showed a continuous fall with each successive increases of NP even upto the highest dose of these ingredients. Total and protein nitrogen in sub-optimal and optimal dressings were not affected markedly; in higher doses of NP, these were markedly increased. Protein N expressed as percentage of total nitrogen slightly increased under NP application upto four times the standard dose of these ingredients and only showed a fall under highest level of NP.

Straw/grain ratio was increased in response to NP application upto the standard level but *subsequent increases lowered this ratio. Height/tiller* ratio was progressively lowered with each successive additions; the effects on total tiller/ear-bearing tillers though similar were less characteristic.

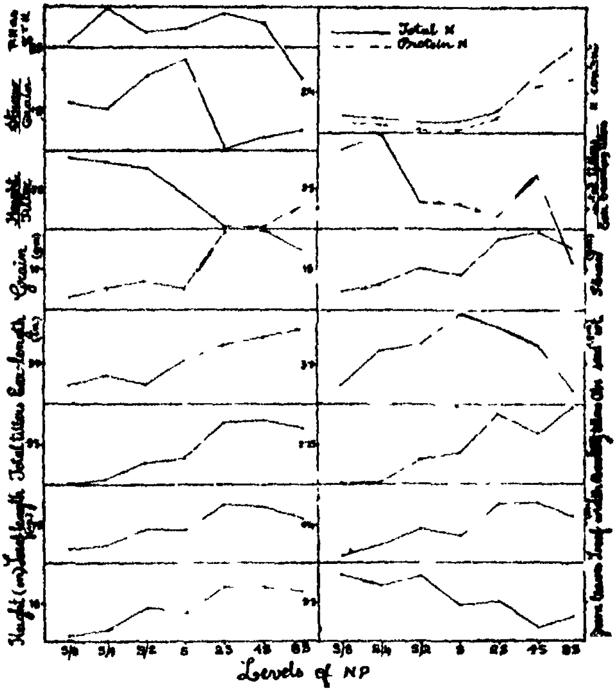

FIG. 4. Effect of increasing levels of NP upon growth characters yield and nitrogen content of wheat grain.

E. Effects of NK upon Growth Characters and Nitrogen Content of Wheat Grain

Simultaneous increases in NK under otherwise constant level of P, also helped in improving majority of growth characters. Increases upto two or four times the standard dose improved vegetative vigour, increased

TABLE IV

Growth characters, yield and nitrogen content of wheat grain as influenced by varying levels of NP

Standard dose of NP = 60 lbs N plus 40 lbs P_2O_5 per acre

Characters		S/8	S/4	S/2	S	2S	4S	8S
1. Mean height (inches)	..	13·86	14 60	17 52	16·97	20·11	20·01	19·77
2 Mean number of green leaves on main shoot		3 88	3·72	3·84	3·48	3·52	3·20	3·32
3. Mean leaf length (in)	..	5 90	6 19	7·23	7 13	8·70	8·59	7·93
4. Mean leaf width (in)	..	0·32	0 35	0 30	0·37	0·47	0·47	0·42
5. Mean number of tillers	..	3 0	3 2	4·25	4 65	6·95	7·0	6·50
6 Mean number of ear-bearing tillers		1·0	1·0	1 8	2 0	3·2	2·6	3·4
7. Ear length (in)	.	4 5	4 88	4 50	5·10	5·50	5 70	5·90
8. Grain yield (gm)	.	3 4	5 0	6 8	5·2	19·6	19·68	14·80
9. Straw yield (gm)	.	6 8	9 6	15·4	12 7	26 0	29·4	23 2
10. Absolute wt. of seeds	.	2 76	3 19	3 24	3·63	3·48	3·24	2·66
11. Height/tiller ratio	.	4 62	4·50	4·35	3·65	2·89	2·86	3·41
12. Straw/grain ratio	..	2 0	1·92	2·26	2·43	1·32	1·49	1·57
13. Total tiller/ear-bearing tillers		3 0	3·2	2·36	2·32	2·17	2·69	1 61
14. Total N % in grain	..	1 775	1·520	1·482	1 492	1·704	2·656	3·285
15. Protein N % in grain	.	1·539	1·449	1 321	1·334	1·592	2 419	2·559
16. True Protein %	.	9·619	9 056	8·256	8·338	11·542	15·119	15·994
17. Protein N as % total nitrogen		86·704	95 329	89·136	89·410	93·432	91·076	77·890

Note—Refer Table I, C D at 5% for grain yield · ± 1·85.

height, leaf length, tillering, ear length, grain and straw yields (Fig. 5, Table V). Number of green leaves on main shoot and absolute weight of seeds were not much affected by level of NK upto two times the standard dose. Highest dose lowered absolute weight but increased green leaves on main shoot. Leaf-width was not markedly affected by supra-optimal doses of NK Total nitrogen and protein N were only increased under heavier doses; proportion of protein nitrogen to toal nitrogen was also higher under supra-optimal dressings of NK.

Straw/grain ratio was improved slightly with each successive application upto optimum; higher doses (heaviest level excepting) lowered this ratio markedly. Ratio of height/tiller and total tiller/ear-bearing tiller also declined with each increase in level of NK.

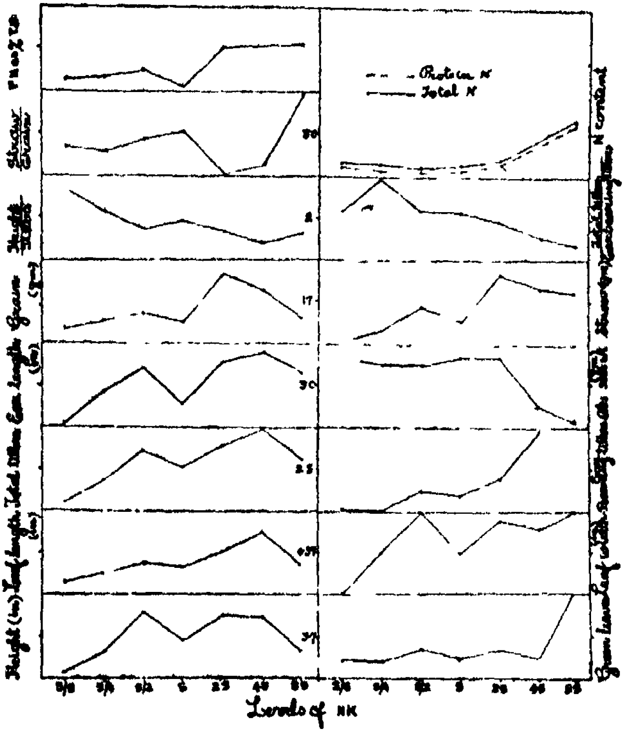

FIG. 5. Effects of increasing levels of N K upon growth characters, yield and nitrogen content of wheat grain.

F. Effects of PK upon Growth Characters and Nitrogen Content of Grain

Barring the standard dose of PK, increases in phosphoric acid and potash under otherwise adequate nitrogen supplies, raised grain, straw and tillering upto 2-4 times the standard levels of these ingredients (Fig 6, Table VI). Leaf size was less markedly affected. Absolute weight of seeds and green leaf number showed tendency to increase under supra-optimal doses of PK. Total nitrogen and protein nitrogen increased upto the standard dose of PK and later decreased with heavier applications. Proportion of protein N to total nitrogen did not vary much under different doses.

Note—Refer Table I; C D at 5% for grain yield ± 1 65.

TABLE VI

Growth characters, yield and nitrogen content of wheat grain as influenced by varying doses of PK

Standard dose of P K = 40 lbs. P_2O_5 and 30 lbs. K_2O per acre

Characters	S/8	S/4	S/2	S	2S	4S	8S
1 Mean height (inches) ..	20·36	19·76	20 63	16 65	19·29	21·16	21·66
2 Mean number of green leaves on main shoot	3·52	3·56	3 25	3·48	3 68	3·64	3·20
3 Mean leaf length (in) ..	7·22	7·79	7·58	6·72	7·87	7·70	8·26
4. Mean leaf width (in) ..	0·43	0·41	0·44	0·37	0·41	0·45	0·48
5 Mean number of tillers ..	4 75	4·60	5 45	4·65	6·10	5·80	5·70
6 Mean number of ear bearing tillers	2·4	2·8	3·0	2·0	3·6	3·0	2·6
7 Ear length (in.) ..	5·8	5 6	5 66	5 1	5·54	5·58	5·48
8. Grain yield (gm) .	13·1	13·6	11·0	5·2	14·6	16·16	15·0
9. Straw yield (gm) ..	24 2	24·2	22 2	12 7	24 8	28·2	26·4
10 Absolute wt. of seeds ..	3·5	3·26	3·27	3·63	3·44	3·90	3·42
11 Height/tiller ratio ..	4 29	4·29	3·75	3·64	3·16	3·60	3·83
12. Straw/grain ratio .	1·84	1 78	2 01	2 44	1·69	1·74	1 69
13 Total tiller/ear-bearing tillers	1 91	1·64	1·81	2·32	1 60	1·93	2·17
14. Total N % in grain N ..	1·401	1 425	1 425	1·492	1·444	1 367	1·425
15. Protein N as % total N .	1·238	1·300	1·315	1·334	1·315	1·269	1·238
16. True Protein %	7 138	8·11	8·219	8·338	8·219	7·931	7 738
17. Protein N as % total nitrogen	88·365	91·228	92·231	89·410	91·066	92·831	86·877

Note—Refer Table I; C.D. at 5% for grain yield : ± 3·50.

TABLE V

Growth characters, yield and nitrogen content of wheat grain as affected by varying levels of NK

Standard dose of NK = 60 lbs. N plus 30 lbs K_2O per acre

Characters	S/8	S/4	S/2	S	2S	4S	8S
1. Mean height (inches)	15·36	16 29	18 19	16 95	18·09	18·01	16 33
2. Mean number of green leaves on main shoot	3·44	3·40	3·56	3 44	3 56	3·44	4 24
3. Mean leaf length (in)	5·74	6·40	6 82	6 65	7·70	8 24	6·61
4 Mean leaf width (in)	0 32	0·37	0·42	0·37	0 41	0·40	0·40
5 Mean number of tillers	2 85	3 80	5·25	4 45	5·60	6·40	4·95
6. Mean number of ear bearing tillers	1·2	1 0	2 2	2 0	3 0	5 8	5·8
7. Ear length (in)	4·84	5·22	5·56	5·10	5 60	5·72	5·44
8 Grain yield (gm)	3 54	5 1	7 0	5 2	16 4	12·8	6·0
9 Straw yield (gm)	7 2	9 8	15·8	12 7	23·4	20 8	19 8
10 Absolute weight of seed	3 63	3 54	3 5	3 03	3·66	2 54	2·19
11 Height/tiller ratio	5 38	4 29	3 46	3·81	3 23	2·81	3·29
12. Straw/grain ratio	2 05	1 93	2 25	2 43	1·44	1·63	3·30
13 Total tiller/ear-bearing tillers	2 37	3 80	2 39	2 22	1 87	1 14	0·85
14 Total N % in grain	1 655	1 501	1 462	1 492	1 693	.	3·618
15. Protein N % in grain	1 491	1 361	1 337	1 334	1 592	..	3·428
16. True Protein %	9·319	8 500	8 356	8 338	9 950	..	21·394
17. Protein N as % total nitrogen	90 091	90 673	91 45	89 41	94·034	..	94·61

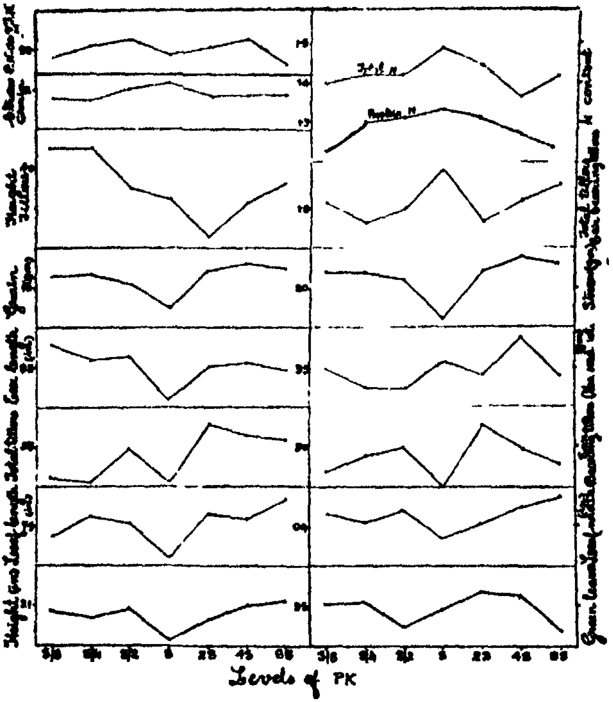

FIG. 6. Effects of increasing levels of PK upon growth characters, yield and nitrogen content of wheat grain.

Straw/grain ratio was higher under standard treatment but remained unaffected in deficient and sufficient cultures. Total tillers/ear-bearing tillers was low under low doses, increased to a peak value under standard treatment and later declined. Supra-optimal doses also showed tendency to increase this ratio but were less effective. Height/tiller ratio declined with each successive addition upto two times the standard dose of PK and later increased with further raising of the dose

G. *Effects of NPK upon Growth Characters and Nitrogen Content of Grain*

When all the ingredients were simultaneously increased, useful effects were noticeable on height, leaf length, leaf width, tillering, ear length, grain and straw yield. Supra-optimal doses of NPK were better in these regards than sub-optimal or optimal doses. Absolute weight of seeds was however, not affected by higher doses beyond that of the standard culture (Fig. 7, Table VII) Total and protein nitrogen on the other hand showed slight fall with increasing NPK upto the standard dose of these ingredients. Increases beyond this raised these markedly. The proportion of protein nitrogen to total nitrogen, however, fell down characteristically.

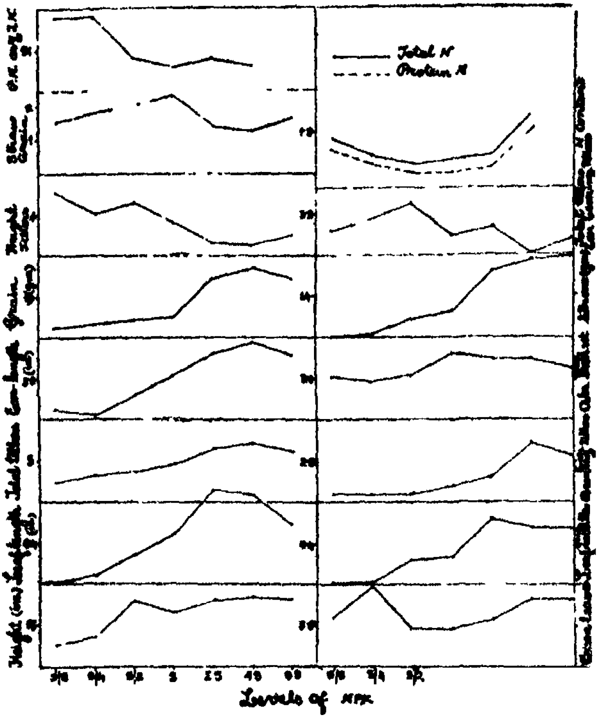

FIG. 7. Effects of increasing levels of NPK upon growth characters, yield and nitrogen content of wheat grain.

Straw/grain ratio increased with each successive addition upto the standard dose of NPK; further rise in fertiliser dose lowered this ratio markedly. Ratio of total tiller/ear-bearing tiller was similarly affected. Height/tiller ratio, on the contrary, declined with each successive applications of NPK.

TABLE VII

Growth characters, yield and nitrogen content of wheat grain as affected by varying levels of NPK

Standard dose of NPK = 60 lbs N, 40 lbs P_2O_5 and 30 lbs K_2O per acre

Characters	S/8	S/4	S/2	S	2S	4S	8S
1. Mean height (inches) .	12 41	13 66	18 05	16 95	18·29	18·48	18 39
2. Mean number of green leaves on main shoot	3·60	3·98	3 48	3 48	3 60	3 84	3 84
3 Mean leaf length (in)	5·45	5 60	6 17	6·69	7·72	7·63	6·92
4. Mean breadth of leaf (in).	0·31	0 30	0 36	0 37	0 46	0 44	0·44
5. Mean number of tillers ..	2·4	3 3	3 9	4·65	6 85	7 1	6 1
6. Mean number of ear bearing tillers	1·0	1 0	1 0	2·0	2·6	3 6	2·8
7. Ear length (in) ..	4 26	4·10	4 64	5 10	5 60	5 94	5·64
8 Grain yield (gm) .	2 6	2 8	4·2	5 2	14·1	17 2	14·0
9 Straw yield (gm)	4·0	5 3	8·7	12·7	20 8	23·7	24·1
10 Absolute wt of seeds	3 02	2 98	3 10	3 63	3 56	3 50	3·26
11. Height/tiller ratio ..	5 17	4·14	4 62	3 64	2 67	2·60	3 01
12. Straw/grain ratio	1·55	1 89	2·07	2 43	1 46	1 38	1 72
13. Total tiller/ear-bearing tillers	2 4	3 3	3 9	2 32	2 63	1 69	2 17
14 Total N % in grain .	1 700	1·512	1·435	1 492	1·531	2 086	..
15 Protein N % in grain	1 617	1 438	1 300	1 334	1·392	1 857	.
16. True Protein % ..	10·108	8·988	8·110	8·338	8 700	11 606	..
17. Protein N as % Total N .	95·116	95 106	90 592	89 410	90 921	89 022	.

Note—Refer Table I, C.D at 5 % for grain yield : ± 4·26

DISCUSSION

Data recorded on the effects of increases in one, two or three ingredients in the culture medium, indicate at least one feature in common in all the series, *viz*, the augmentative effect of such increases upon growth upto a certain level and a toxic or deleterious effect beyond a certain dose The level at which optimal effects were noticeable varied from two to four times the standard dose in the different series of cultures The effects of these optimal doses have been found to be statistically significant from the point of view of grain yield Deficient supplies of nitrogen in doses lower than the optimal, resulted in lower height, smaller width, poor tillering and low fertility of tillers, shorter ear length, poor grain and straw yields, low protein content and high total tiller/ear-bearing tiller and height/tiller ratios Sufficiency of nitrogen (nitrogen beyond the optimum dosage) had a harmful effect upon majority of growth characters, grain and straw yield, but were useful from the point of view of protein content of grain, proportion of protein nitrogen to total nitrogen was also slightly improved. Excess of nitrogen also produced plants with low height/tiller and total tiller/ear-bearing tiller ratios.

Sub-optimal phosphoric acid dressings (deficiency of P) produced plants with low vegetative vigour, poor height and tillering, greater height/tiller ratio, low grain and straw yields and poor straw/grain ratio. Supra-optimal dressings (sufficiency of P) had marked augmentative effect upon tillering and height, but very little effect upon yield of grain and straw; height/tiller and straw/grain ratios were markedly reduced While protein nitrogen was not markedly affected, the proportion of protein to total nitrogen was slightly improved in sufficiency cultures indicating thereby the better ability of the plant to convert inorganic nitrogen into organic nitrogenous compounds.

Deficiency of potash under otherwise adequate supply of nitrogen and phosphoric acid, resulted in useful effects: high tillering, larger ear length, greater straw and grain yields, relatively high protein and total nitrogen content, low total tiller/ear-bearing tiller ratios were the characteristic physiological symptoms of potash deficiency. Leaf characters did not respond so characteristically. Sufficiency of potash improved leaf size tillering, grain and straw and total and protein N but lowered total tiller/ear-bearing tiller and height/tiller ratios

Deficiency of both nitrogen and phosphoric acid retarded vegetative vigour and development of all growth characters. Poor height and tillering shorter ear length and leaf size, smaller absolute weight of seeds and low grain and straw yields were noted Height/tiller and total tiller/ear-bearing tiller ratios were high. Sufficiency of NP caused deleterious effects on absolute weight, reduced grain and straw, lowered height/tiller total tiller/ear-bearing tiller and straw/grain ratios but improved nitrogen content of grain.

NK deficiency also resulted in poor height and tillering, small leaf size and ear length, low grain and straw yields but high height/tiller and total tiller/ear-bearing tiller ratios. Sufficiency effects of NK were most marked on increased protein and total nitrogen content of grains, high tillering, greater ear length but poor development of plant in other directions.

PK deficiency under adequate nitrogen manuring was useful from the point of view of ear length, grain and straw and height/total tiller ratio. The latter was noted to be unusually high indicating lack of production of shoots in proportion to increases in height of plants. Sufficiency of these two ingredients caused better development of leaves, greater absolute weight of seeds and higher yields of straw and grain. Effects on nitrogen content of grain were identical inasmuch as sufficiency and deficiency of PK both lowered the amount of nitrogen in seeds.

Increasing deficiency of all the three ingredients NPK was associated with all-round poor development of plant, low grain and straw yield but greater height/tiller ratio. Sufficiency of these had no appreciable effects upon grain or straw yields nor were the effects injurious from the point of view of development of the plant. Low height/tiller and total tiller/ear-bearing tiller ratios and high protein and total nitrogen content along with useful effects on all characters were the important effects of sufficiency of all the three ingredients

Judged from the straw/grain ratio obtained in different cultures, deficiency of all the ingredients (K excepting), *viz*., N, P, NP, NK, PK and NPK lowered vegetative growth more in proportion to reproductive growth. Sufficiency effects of all these fertilisers were also more or less identical. High yet balanced vegetative and reproductive growth was only recorded under the standard doses. Again, in majority of the cultures, high yield of grain was associated with low height/total tiller ratio. The greater the production of tillers relative to shoot elongation, the lower was the height/tiller ratio and the greater appeared to be the chances of a particular nutrient ratio to exhibit high yield

On total nitrogen and protein content of grain, the effects of sufficiency of nitrogen whether applied alone or with P or K was decidedly very beneficial. In absence of supra-optimal nitrogen doses as in PK, K, and P series of cultures, augmentative effect was not so evident; under such conditions of nitrogen supply, deficient or sufficient PK, K and P cultures behaved identically. Indications were however, evident in the NPK series of cultures that deficiency of all these entities was slightly better than standard cultures in improving nitrogen content of grain. Nutrient status of the medium thus markedly affected growth and protein accumulation in wheat. Further discussion of the nutrient effects shall be taken up in later communications.

SUMMARY

These investigations deal with the deficiency-sufficiency effects of nitrogen, phosphoric acid and potash, on the growth behaviour and nitrogen content of wheat grain. Eight series of cultures were maintained. In each case plants were grown in well washed sand and the levels of fertilisers varied from a low level of deficiency to high doses of sufficiency so as to induce marked variations in the nutrient status of the culture media. The following were the deficiency-sufficiency effects of different fertilisers;

Nitrogen deficiency caused lower height, smaller width of leaves, poor tillering, low fertility of tillers, shorter ear length, poor grain and straw yield, low protein and high height/tiller and total tiller/ear-bearing tiller ratios.

Nitrogen sufficiency improved protein content and produced plants with low height/tiller and total tillor/ear-bearing tiller ratios

Phosphorus deficiency induced poor vegetative vigour, poor height, fewer tillering, low straw and grain, and reduced straw/grain ratio; height/tiller ratio was greater.

Phosphorus sufficiency caused marked improvement in tillering and height but reduced height/tiller and straw/grain ratios. Proportion of protein N to total N was slightly high.

Potash deficiency induced high tillering, larger ear length, greater straw and grain, high protein content but low total tiller/ear-bearing tiller ratios.

Potash sufficiency improved leaf size, tillering, grain and straw yields; total and protein nitrogen in grain was raised. Total tiller/ear-bearing tiller ratio was lowered

Potash effects were almost identical in all the sufficiency and deficiency cultures

Deficiency sufficiency effects of NP, NK and NPK were largely predominated by the relative quantity of nitrogen present and not so much by the complimentary dose of P and K. In PK deficiency cultures, the effects were predominated by the relative quantities of both P and K Distinctive symptoms produced in each case have been discussed.

Balanced vegetative and reproductive growth were recorded under the standard fertiliser culture High yields were invariably associated with low height/tiller ratios in all the nutrient cultures; high protein content of seeds however, was not necessarily associated with high grain yield

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LATENT WITHER-TIP INFECTION ON CITRUS

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In most of the citrus gardens of the Central Provinces and Berar, small pinkish-white fungal areas, varying from half an inch to two inches in diameter, were observed on trunks and main branches of orange plants Twigs measuring more than half an inch in diameter were also occasionally infected. Water-shoots and young twigs were always found free from the infection, These thin crust-like small areas may either be scattered on different parts of a branch or some of them may coalesce together forming larger patches, In almost every garden, where wither-tip disease happened to occur in severe form, these patches were found in abundance and were specially noticeable in localities like Nagpur, Saoner, Rasoolabad, Jalgaon, Burhanpur, Pandhurna and Dhamtari. Mosambi plants at Saoner and Pandhurna were also found covered with such patches.

It has been observed that during summer months, the mycelium of the fungus survives in the form of pink coloured stroma in small cracks in the bark of orange or mosambi trees and persists as inter- and intra-cellular parasite in one or two layers of the cortical tissue An examination of the fungus proved it to be *Colletotrichum gloeosporioides* Penz.

Branches of three-year old orange plants were artificially inoculated with pure cultures of the pathogen. Typical symptoms of wither-tip disease with severe die-back of the young shoots appeared after four weeks of inoculation and were specially marked under humid conditions. Pinkish-white patches were formed on the inoculated branches of the plants. On reisolation and examination, the fungus proved to be identical to the strain of *Colletotrichum gloeosporioides* by which it was inoculated

On rice-meal agar medium the fungal colony appears pink in colour, with dark-brown pin-head like acervuli dotted all over the surface. Small hyphal knots are produced. Aerial mycelium is scanty and irregular. The hyphæ are first hyaline but later turn light-black in colour, varying in diameter from 2·9 to 7 μ (average 4·17 μ). Spores are unicellular, oval in shape with two to three oil globules and in mass present a pinkish appearance The size of the spores vary, breadth from 4·13 to 7 μ and length 8·46 to 15·0 μ (average 5 5 by 13·0 μ). The dimensions of the acervuli are variable. The setæ, measuring 56 to 133 μ in length, are four to five celled with a gradually tapering terminal cell; the two basal cells presenting a jointed appearance. At the two ends of an acervules the setæ are longer and broader than those in the middle.

Investigations of several authors have given strong reasons that the size and shape of the spores of *Colletotrichum gloeosporioides* are extremely variable. Penzig's[5] (1887) measurements are 16 to 18µ by 4 to 6µ while that of Rolfs[6] (1904) 10 to 16µ by 5 to 7µ Burger[3] (1921) has found great variability in spores of different strains of this fungus, the mean length varied from 11·5 to 20·3µ and the mean width of the same strain varied from 3·2 to 6·4µ Chaudhari[4] (1936) has isolated four strains and has mentioned that the length of the spores vary from 11·2 to 21·0µ and the breadth from 2·4 to 7·0µ, the mean values being 13·0µ and 5·5µ respectively which corresponds to the mean values of the spores of the strain of *C gloeosporioide* isolated by author Baker, Crowdy and McKee[2] (1940) in reviewing the progress of investigations in latent infection by *C. gloesporioides* and allied species state that numerous isolations of the fungus from grape-fruit and papaws fall into three groups. The strain of *C gloeosporioides* isolated by the author appears somewhat similar to the strain A, No. 316 mentioned by Chaudhari[4] (1936) and falls more or less within the second group of Baker, Crowdy and McKee[2] (1940)

Baker[1] (1938) had described the occurrence of latent infection in citrus fruits due to *Colletotrichum gloeosporioides* and mentions that in Trinidad dead wood bore conidia of the fungus The presence of the acervuli of *C. gloeosporioides* on dead wood has invariably been observed by the author It has been further noticed that in spite of systematic and severe pruning of the diseased trees in a garden, wither-tip disease appeared during the periods of low temperature and high humidity, and produced die-back symptoms It therefore appears that the persistence of *C. gloeosporioides* in small pockets and cracks on the main branches and trunk is in every likelihood a method to tide over the unfavourable atmospheric conditions of the Central Provinces and Berar as they are specially apparent during summer months of high temperature and low humidity. With the advent of high humidity and low temperature during rainy months, the fungus becomes active and gives rise to wither-tip disease. Further study on the problem is in progress.

SUMMARY

1. Small pinkish-white fungal areas of *Colletotrichum gloeosporioides* Penz. were observed on trunks and main branches of orange plants. In certain localities mosambi plants were also infected.

2. Water shoots and young twigs were always found free from the infection.

3. During summer months the mycelium of the fungus survives in the form of pink coloured stroma in small cracks in the bark of orange or mosambi trees and thus tides over the unfavourable atmosphere condition.

4. Mycelium on the host persists as inter- and intra-cellular parasite in one or two layers of the cortical tissue.

5. The disease could be induced artificially

6. Measurements of the spores, setæ and hyphæ are given.

7. The isolated strain of *C. gloeosporioides* corresponds to strain A, No. 316 of Chaudhari and practically falls within the second group of Baker, Crowdy and MeKee.

8. Acervuli of the pathogen has been observed on dead wood also

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THE NATURE OF PROTEINASES OF THERMOPHILIC BACTERIA

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The proteolytic enzymes of bacteria and molds have not been sufficiently studied and the nature and type of microbial proteinases are still imperfectly understood. An exact knowledge of the type of bacterial proteinases should be of interest not only from the theoretical point of view but also in its application to the study of attack and degradation of animal and plant tissues, the study of proteolytic phenomenon in soil, the investigations on storage and deterioration of foodstuffs and the investigations on some industrial processes. While most workers are agreed that bacterial proteinases cannot be classified with the pepsinases, opinion is divided as to whether these proteinases are of papainase type or tryptase type

Dernby and Blanc (1921) had found that culture filtrates of several anærobes bacteria digest gelatin optimally at pH 6 from which they concluded that the proteinase is of a tryptic nature. Kendall and Keith (1926) and Schierge (1926) working with *Bacillus proteus* and *B. coli* respectively have also concluded that their proteinases are of tryptic nature, the optimum hydrogen-ion concentration in the latter case was stated to be at pH 6·0 to 6·6. These conclusions must be revised because tryptases optimally hydrolyse markedly cationic form of protein Walbum and Reymann (1934) and Bessey and King (1934) have obtained conflicting results with *Clostridium histolyticum*. In several papers Maschmann (1937, 1938) has published his results with *Bacillus pyocyaneus*, *B prodigiosus*, *B. fluorescence*, *B perfrigens*, *B. histolyticum* and *B botulinus*. Many of these micro-organisms produce a proteinase whose optimum pH is 7 and is activated in some cases by hydrocyanic acid and by thiol compounds. Weil and Kocholaty (1937) and Kocholaty, Weil and Smith (1938) have studied *Clostridium histolyticum* and by measuring proteolytic activity by estimating the liberation of free α-amino acids they have found that *Cl. histolyticum* produces a proteinase which is active optimally at pH 7, is activated by thiol compounds and is inert towards enterokinase.

The micro-organisms studied by the present author were the typical thermophilic bacteria *Bacillus thermophilus, B arothermophilus* and *B. thermoacidurans*. 'Cultures of these were obtained from the Lister Institute, London. The thermophilic bacteria can grow at high temperatures, often close to the coagulation temperature of their albumins. This renders them an intriguing subject for study. These bacteria are widely distributed in soil, etc., and their proteolytic activities are called into play in several processes of importance in soil science, in agriculture and in industry. Clark and Tanner (1937) and McMaster (1934-5) have shown the importance of thermophiles in food preservation. A commonly occurring spoilage of soya beans has been ascribed to the proteolytic action of *B. thermophilus* by Rokusho and Fukutome (1937) Thermophilic bacteria are active agents in manure fermentation, see for example, Dunez (1933) and Damon and Ferrer (1925). Proteolytic thermogenesis of wool has been studied by Barker (1929) and according to James (1928) nitrogen metabolism and thermogenesis are interrelated The harmful heating up of hay, fodder, textile materials and thermophilic fermentation in the processing of tobacco, cocoa and coffee are well known and thermophilic bacteria undoubtedly play a part in these.

All earlier investigations on the nature of microbial proteinases are based on the determination of pH optimas and response towards papainase and tryptase activators and inhibitors. In the present investigations, in addition to studying these aspects, an attempt has been made, by duplicate enzyme experiments, to determine whether or not the peptide bonds, in the protein molecule, hydrolysed by the bacterial proteinases are identical to those hydrolysed by either pepsin, papain or trypsin or *vice versa*.

The experimental technique adopted was quite simple. The bacteria were grown in nutrient broth by incubation at 50° C for forty-eight hours. The cultures were centrifuged and filtered through Chamberland candles. This yielded cell-free proteolytically powerful filtrates free from peptonase or polypeptidase. Substrates used were gelatin, egg albumin and casein made into aqueous solution at the appropriate pH with McIlvaine's citrate-phosphate buffer. Proteolytic hydrolysis was allowed to proceed at 40° C. in presence of a drop of toluene. 2 ml. of the proteinase filtrate were used per 20 ml. of substrate solution. In case of gelatin the initial stages of proteolysis were followed viscometrically. With egg albumin the initial stage of proteolysis was followed by precipitating the unaltered protein by boiling at the isoelectric point or by precipitating the unaltered protein, meta-proteins and albumoses in 4% trichloracetic acid followed by estimation of the fraction which was soluble under these conditions.

In all cases the increase in free α-amino groups, during incubation at 40° C. for forty-eight hours, was estimated by the micro Van Slyke method or by the titration method.

pH OPTIMUM OF PROTEINASES OF THERMOPHILIC BACTERIA

2 ml. of proteinase solution were added to 20 ml. of 3% gelatin solution at pH ranging from 3 to 10 Initial rate of hydrolysis was calculated by extrapolating viscosity time curves to zero time and also per cent. fall in initial viscosity in 30 minutes was determined Finally the increase in α-amino acids during incubation at 40° C for 48 hours was estimated by Van Slyke's method In case of egg albumin 2 ml of the proteinase solution were added to 20 ml. of the protein solution containing 1·3 to 1·4 mgm. of organic nitrogen per ml The nitrogenous matter not precipitated by boiling at isoelectric point or in 4% trichloracetic and the amount of free α-amino nitrogen were estimated before and after incubation. In case of casein also proteolysis was followed by estimation of free α-amino acids. In all cases pH curves were plotted from which the values for optimum pH were derived. These were as follows:—

TABLE I

Proteinase of	Gelatin	Egg albumin	Casein
B thermophilus	8·3	8·0	7·7
B aerothermophilus	7·7	8·0	7·3
B thermoacidurans	8·1	8·0	7·5

Thus all these proteinases are optimally active in the alkaline region, *i e*, they hydrolyse the cationic form of proteins In this respect therefore they resemble the tryptases rather than the papainases or the pepsinases.

EFFECT OF PAPAINASE ACTIVATORS ON THE PROTEINASES OF THERMOPHILIC BACTERIA

The substrate used was 3% gelatin solution prepared at the respective pH in McIlvaine's citrate-phosphate buffer The enzyme solution was incubated with the activating reagent at 30° C. half an hour before mixing with the substrate. In case of hydrogen cyanide or hydrogen sulphide the gas was bubbled through the cold enzyme solution for a few minutes and the solution was then incubated in a stoppered test-tube at 30° for half an hour.

TABLE II

Reagent	Concentration	% Fall in initial viscosity in first 5 minutes	% Fall in initial viscosity in 30 minutes	Increase in α-amino nitrogen mgm./10
		B thermophilus		
None ..		6·72	48·05	5·85
Hydrogen sulphide .		6·01	42·10	5·27
Hydrogen cyanide ..		6·05	42·60	5·29
Cystein .	M/250	6·63	46·90	5·29
		B aerothermophilus		
None ..		6·03	41·05	5·27
Hydrogen sulphide		5·90	40·00	5·21
Hydrogen cyanide ..		5·96	40·65	5·30
Cystein ..	M/250	6·00	41·00	5·29
		B thermoacidurans		
None ..		6·35	45·90	5·91
Hydrogen sulphide .		6·00	42·55	5·32
Hydrogen cyanide ..		6·27	44·95	5·46
Cystein ..	M/250	5·32	45·35	5·57

It is therefore obvious that the typical papain activators do not activate the proteinases of thermophilic bacteria In fact there is a very slight inhibition in some cases

EFFECT OF PAPAINASE INHIBITORS ON THE PROTEINASES OF THERMOPHILIC BACTERIA

The experimental and analytical methods used were the same as in the previous experiment.

TABLE III

Reagent	Concentration	% Fall in initial viscosity in first 5 minutes	% Fall in initial viscosity in 30 minutes	Increase in α-amino nitrogen mgm./10 ml.
		B. thermophilus		
None .		6·25	48·70	5·88
Iodacetic acid ..	M/250	6·18	47·90	5·78
Hydrazine ..	M/200	6·35	46·05	5·79
Copper sulphate .	M/200	6·29	47·00	5·85
		B aerothermophilus		
None ..		6·20	41·55	5·28
Iodacetic acid ..	M/250	6·15	41·25	5·35
Hydrazine ..	M/200	6·22	41·20	5·22
Copper sulphate ..	M/200	6·16	41·90	5·29
		B. thermoacidurans		
None ..		6·36	46·15	5·59
Iodacetic acid ..	M/250	6·36	46·10	5·62
Hydrazine ..	M/200	6·32	46·50	5·57
Copper sulphate ..	M/200	6·30	46·20	5·60

Obviously therefore the typical papainase inhibitors have no significant effect on the proteinases of thermophilic bacteria.

EFFECT OF ENTEROKINASE ON THE PROTEINASES OF THERMOPHILIC BACTERIA

Enterokinase was prepared freshly from swine duodenum and was freed from trypsin by fractional precipitation with ammonium sulphate Its activity was checked against crude pancreatic extracts. The preparation showed negligible proteolytic activity by itself when tested against gelatin. For examining its effect on microbial proteinases the powder was mixed with the proteinase solution and the mixture was incubated at 30° C. for one hour with occasional shaking.

TABLE IV

Proteinase of	Without enterokinase			With enterokinase		
	% Fall in initial viscosity in first 5 minutes	% Fall in initial viscosity in 30 minutes	Increase in α-amino nitrogen mgm./10 ml	% Fall in initial viscosity in first 5 minutes	% Fall in initial viscosity in 30 minutes	Increase in α-amino nitrogen mgm /10 ml.
B thermophilus	6 83	47·50	6·11	6 84	47·05	6·07
B. aerothermophilus	6·44	45·95	5 65	6·40	46 15	5 59
B. thermoacidurans	6 66	43·15	5·31	6·00	43 00	5·38

The above data shows that enterokinase, the specific activator of the tryptases, has no effect on the proteinases of thermophilic bacteria.

EFFECT OF PEPSIN, PAPAIN AND TRYPSIN ON GELATIN SOLUTIONS PREVIOUSLY HYDROLYSED BY THE PROTEINASES OF THERMOPHILIC BACTERIA

Most proteinases do not open up all the peptide bonds in the protein molecule. For example papain can open up more peptide bonds after a gelatin solution has been digested to completion with an excess of trypsin or pepsin and *vice-versa* The same is the case when trypsin is allowed to act on a gelatin solution previously hydrolysed to completion by an excess of pepsin and *vice-versa*. In the present experiment 200 ml. each of 3% gelatin solution were incubated with 40 ml. each of highly powerful solutions of the proteinases of *Bacillus thermophilus*, *B. aerothermophilus* and *B. thermoacidurans* respectively for several days at optimum pH till there was no further increase in free α-amino acids. Each solution was then divided into four portions and the pH of three of these four portions was re-adjusted to the respective optimum pH of pepsin, papain and trypsin. With the fourth portions the pH was restored to the original starting pH as there had been a slight fall in pH during the prolonged proteolysis. The four lots of 50 ml. each comprising each of the three sets were then subjected to the action of pepsin, papain, trypsin and fresh culture filtrate of the same bacteria respectively. Incubation was carried out at 40° C for 36 hours in presence of toluene.

TABLE V

Increase in free α-amino nitrogen, mgm/10 ml.

First proteinase	Second proteinase				
	Blank (distilled water)	Same as first	Pepsin	Papain	Trypsin
B thermophilus ..	Nil	0·13	1·38	3·95	2·05
B aerothermophilus .	,,	0·11	1·02	4·01	2·86
B thermoacidurans .	,,	0·08	1·40	3·13	2·95
Pepsin ..	,,	0·06	0·06	4·02	3·39
Papain	,,	0·09	1·52	0·09	3·22
Trypsin .	,,	0·10	1·30	3·09	0·10

It is therefore obvious that gelatin contains some peptide bonds which cannot be opened by the microbial proteinases but which are available for attack by pepsin, papain and by trypsin. From this it would appear that the type specificity and mode of attack of the proteinases of the thermophilic bacteria is different from that of either pepsin, papain or trypsin, just as the type specificity and mode of attack of pepsin, papain and trypsin is different from that of each other.

It was now decided to investigate if either one or more of the three typical proteinases pepsin, papain and trypsin can hydrolyse all those peptide groups which are hydrolysable by the proteinases of the thermophilic bacteria.

EFFECT OF PROTEINASES OF THERMOPHILIC BACTERIA ON PEPTIC, PAPAIN AND TRYPTIC DIGESTS OF GELATIN

The experimental methods were the same as in the previous experiment except that the positions of bacterial proteinases on the one hand and those of pepsin, papain and trypsin on the other were reversed. In order to remove any possibility of doubt the first series of hydrolysis was conducted with papain activated with hydrogen cyanide and with trypsin activated with enterokinase.

TABLE VI

Increase in α-amino nitrogen, mgm /10 ml

First proteinase	Second proteinase				
	Blank (distilled water)	Same as first	*B thermophilus*	*B aerothermophilus*	*B thermoacidurans*
Pepsin	Nil	0·12	5·12	4·44	4·72
Papain-HCN	"	0·04	3·69	2·95	2·35
Trypsin enterokinase	"	0·06	3·45	3·67	2·95

Therefore the bacterial proteinases can hydrolyse certain peptide groups that can be hydrolysed neither by pepsin nor by papain or trypsin. From Table VI it appears that the increase in α-amino nitrogen in the second hydrolysis is greater with all three bacterial proteinases if the first hydrolysis is carried out with pepsin. This accords with the fact that pepsin is mainly a disaggregating enzyme

DISCUSSION AND SUMMARY

The nature and type of bacterial proteinases has been the subject of a certain amount of discussion in the past and conflicting opinions have been expressed as to whether these proteinases are peptic, papainase or tryptic in nature. Previous investigators have studied the degree and optimum pH of hydrolysis and activation-inhibition behaviour of the bacterial proteinases and have attempted to classify them with pepsinases, papainases or tryptases. The results of studies of this type afford an insight into the nature and properties of the proteinases In the present investigations a study has been made of the optimum pH and activation-inhibition properties of the bacterial proteinases and in addition attempts have been made to investigate if the bacterial proteinases attack peptide bonds which are identical with or entirely or partially different from those hydrolysed by pepsin, papain and trypsin or *vice-versa*. All the three bacterial proteinases studied here hydrolyse gelatin, casein and egg albumin optimally in the alkaline region, *i e*, like the tryptases they hydrolyse the cationic form of proteins. They are not activated by papain activators and are not inhibited by papain inhibitors. Likewise they do not respond to trypsin activators Gelatin solutions which have already been subjected to prolonged hydrolysis by pepsin, papain or trypsin and which cannot be further hydrolysed by these three proteinases are further hydrolysed by the bacterial proteinases. Conversely gelatin solutions which have already been hydrolysed to completion by the bacterial proteinases can be further hydrolysed by pepsin, papain or trypsin. This shows that the peptide bonds opened up by the bacterial proteinases are at least partially different from those hydrolysed by either pepsin, papain or by trypsin. From these results it is obvious that out of the three main categories of proteinases, *i e*, the pepsinases, papainases and tryptases the evidence in favour of the bacterial proteinases studied here belonging to the tryptic class of proteinases is relatively the strongest. But there are also points of difference between the bacterial proteinases and tryptases. The former do not respond to trypsin activators This may be due either to the fact that the bacterial proteinases are not of tryptic nature or else that when they are obtained in the culture filtrates they are already in the fully active state. The results of duplicate enzyme experiments have shown that the bacterial proteinases hydrolyse peptide bonds which are at least partially different from those hydrolysed by trypsin and *vice-versa*. On the whole it would appear to be more satisfactory to avoid classifying microbial proteinases with any of the three main groups of proteinases but rather to leave them in a class by themselves.

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POWDERY MILDEW OF BETEL VINES

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OF recent years powdery mildew has been doing much damage to betel vines grown at Bassein and Kelva Mahim, near Bombay, but it has not been reported from other parts of the Province where this crop is also extensively cultivated. It makes its appearance in the cold season and almost disappears as the hot weather approaches. Older plantations are more liable to attack than newly established gardens

The disease is caused by a species of *Oidium*, which was first reported from Ceylon by Stevenson (1926), and later by Mitra (1930) from Burma and by Narasimhan (1933) from Mysore The causative fungus, however, has not been described, and in the following pages a short account of the organism and the disease caused by it, is given.

SYMPTOMS

The disease is easily recognised by the appearance of yellow spots which are slightly raised and irregular in outline and correspond in extent to white powdery patches of mildew on the under-surface of the leaves These patches are also sometimes found on the upper surface of the leaves They are at first small but increase in extent as they grow together They vary in diameter from a few mm. to 40 mm, and are covered with sparse and dusty growth of the fungus In severe attacks, the patches are covered with fairly thick growth, and are then greyish in appearance Young leaves, if severely attacked, cease to grow and are often deformed The surface of diseased leaves is cracked, and their margins are turned in. Such leaves are pale and hard looking, and drop down at the slightest touch. No other part of the vine is attacked

MORPHOLOGY OF THE FUNGUS

The vegetative mycelium of the fungus is superficial and consists of delicate, white, septate hyphæ, frequently branched and more or less densely interwoven The hyphæ are 5 to $8 \cdot 2\mu$ wide, and from their under-surface arise slender tubes which at once pierce the cuticle and, after entry into the interior of the epidermal cells, swell into globular sacs, the haustoria (Fig 1,A).

Appressoria also develop from the hyphæ at points where the latter are closely applied to the surface of the leaf, and function as holdfasts (Fig. 1, E).

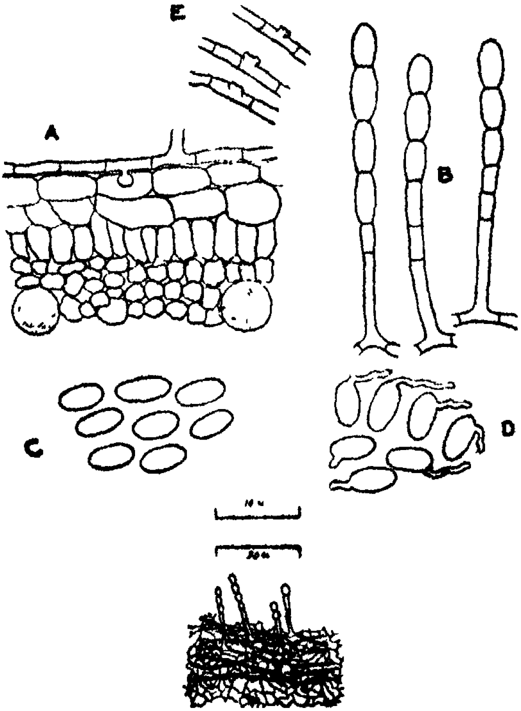

FIG 1. *A* Transverse section of an infected leaf showing a globular haustorium. *B*. Conidiophores bearing elliptical conidia in chains. *C*. Conidia showing the range of shapes and sizes. *D*. Germinating conidia. E Appressoria on the under-surface of superficial hyphæ (A–E × 280) *F*. Portion of a leaf showing septate mycelium, forming a tangled web of much branched hyphæ; conidiophores and conidia (× 56).

After the fungus is well established on the leaf, the prostrate, superficial mycelium gives rise to conidiophores which are erect, simple and usually 2–3 septate (Fig. 1, B and F). These measure 66 to 132μ long, and bear on their ends conidia in chains of 3 to 10 in basipetal succession (Fig. 1, B and F). The conidia are unicellular, colourless and elliptical or barrel-shaped, and measure 20·4–74·7 × 6 8–23·8μ (Fig. 1, C). It will be seen from Table I that, although widely differing lengths of conidia are encountered, a vast majority of them fall between 34 and 47·5μ. The range of variation in width, however, is not large as about 80 per cent. of conidia fall in the classes between 13·7 and 20·4 μ.

TABLE I

Summarised measurements of conidia of Oidium *on* Piper betel

Classes in μ	Length Number of conidia in 400	Classes in μ	Width Number of conidia in 400
20 to 26·9	21	6·8 to 10·2	1
27 to 33·9	68	10·3 to 13·6	80
34 to 40·9	134	13·7 to 17·0	152
41 to 47·9	147	17·1 to 20·4	167
48 to 54·9	14		
55 to 61·9	11		
62 to 68·9	4		
69 to 75·9	1		

Conidia are produced in large numbers and freely germinate by protrusion of a germ tube (Fig. 1, D). These are short-lived and lose their power of germination if exposed to hot, dry conditions In the cold season, the climatic conditions are very favourable so that conidia are shed in abundance and are freely disseminated to adjacent healthy plants Under such conditions, powdery mildew spreads rapidly and is very destructive. At the approach of the hot weather, the growth of the fungus is arrested, and the mildew practically ceases to exist.

CONTROL

As an ectophyte, powdery mildew of the betel vine is amenable to treatment with finely powdered sulphur. Beginning with 1934-35 season, extensive trials on control of mildew were carried out for four years at Bassein and Kelva Mahim in Thana district Superfine sulphur of the order of 325 mesh fineness was used in these tests and was applied to the vines with a crank duster. Results of these trials show that the number of dust applications and the total dressing per acre vary with the age of the plantation. In newly established gardens about 3 to 6 months old, a single dusting of sulphur at the rate of 25 to 30 lb per acre given about the middle of December gave complete protection from mildew. In older plantations varying in age from 12 to 24 months, however, two applications of dust were necessary to control the disease, and the best results were obtained when the second application was made about three weeks after the first, *i.e.*, early in the second week of January. The quantity of sulphur dust required to cover an acre of the crop in two operations varied from 70 to 85 lb.

The dusted leaves are quite normal and do not suffer from any ill-effects. In the absence of the treatment, however, it often becomes necessary to pluck the leaves from the vines before they are fully mature as otherwise they are disfigured by spots and fall to the ground if infection is severe. Sulphur dusting thus not only affords complete protection from the disease but has the effect of prolonging the life of the leaves which can be harvested to suit the market requirements.

DIAGNOSIS

The perithecial phase of the fungus has not been encountered, and accordingly, it is proposed to establish it as a species of *Oidium* with the diagnosis as follows:—

Oidium piperis, spec nov —Mycelium superficiale, ramosum, hyalinum, septatum, 5–8·2μ diam , efformans sparsum vel crassum integumentum in inferiore facie foliorum; haustoria globosa. Conidiophori erecti, simplices, ut plurimum bis vel ter septati, longitudine 66–132μ Conidia unicellularia, hyalina, elliptica vel doliaria, 20·4–74·7 × 6·8–23·8μ, saepissime 34–47·5 × 13·7–20·4μ, catenulatim disposita 3–10, germinatia tubo producto

In foliis viventibus Piperis betle L. in loco Bassein, in distr. Thana, Bombay, India.

Typus positus in Herb. Colleg. Agricult , Poona, atque in Herb. Mycol. Instit., Kew, in Anglia.

Mycelium superficial, branched, hyaline, septate, 5 to 8·2μ in diameter, forming sparse or thick coating on under-surface of leaves, haustoria globular. Conidiophores erect, simple, usually 2–3 septate, ranging from 66 to 132μ in length Conidia unicellular, hyaline, elliptical or barrel-shaped, extremes ranging from 20·4 to 74·7μ in length and 6·8 to 23·8μ in width, mostly 34 to 47·5 × 13·7 to 20·4μ, borne in chains of 3 to 10, germinating by a tube.

On living leaves of *Piper betle* L. at Bassein in Thana District, Bombay, India.

Type specimen deposited in Herb. College of Agriculture, Poona, and Herb. Mycol. Inst., Kew, England.

SUMMARY

The fungus causing powdery mildew of betel vines is described as a new species of *Oidium*. The symptoms of the disease, which is localised at

Bassein and Kelva Mahim in Thana District of Bombay Province, are described. Powdery mildew can be easily checked by dusting betel vines with finely powdered sulphur.

The writers are grateful to the Rev H Santapau, S.J., of St. Xavier's College, Bombay, for rendering the description of the fungus into Latin.

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STUDIES ON COTTON JASSID (*EMPOASCA DEVASTANS* DIST.) IN THE PUNJAB

X. Host Plants

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INTRODUCTORY

The cotton Jassid (*Empoasca devastans* Dist.) is active throughout the year. During the off-season of cotton it thrives on various other host-plants. Even during the cotton-growing period it is found on many food plants other than cotton and there are some which are preferred to it. A thorough knowledge of alternate host-plants of a pest is very essential as this information is very useful in devising measures for its control.

Bhatia (1932) has mentioned the following host-plants of *E. devastans* in the Punjab:—

'Bhindi' (*Hibiscus esculentus*), hollyhock (*Althea rosea*), potatoes (*Solanum tuberosum*), brinjal (*Solanum melongena*), castor (*Ricinus communis*), artichoke (*Cynara scolymus*). He recorded some specimens of adults from 'sem' (*Dolichos lablab*) and 'kalitori' (*Luffa ægyptiaca*) but the pest did not breed on these.

Cherian and Kylasam (1938) in addition to the abovementioned plants have recorded sunflower (*Helianthus annus*) as an alternate host plant in Madras, though Husain and Lal (1940) have expressed their doubts regarding it.

Rajani (1940) reported 'bhindi', brinjal, potato, 'falsa' (*Grewia asiatica*), hollyhock and 'kanghi buti' (*Abutilon indicum*) from Sind.

Husain and Lal (1940) have finally listed following plants as alternate hosts in the Punjab:—Hollyhock, castor, brinjal, potato, 'bhindi', 'ban kápas' (*Hibiscus vitifolius*), 'sunkukra' (*Hibiscus cannabinus*) and some cucurbits.

Afzal (1940) has mentioned 'bhindi', potato, brinjal and hollyhock as food-plants during non-cotton period. Both nymphs and adults were met with on these plants. It was shown experimentally by breeding the pest that castor is not its host plant. The jassid met with on castor belongs to some other species.

It is very unfortunate that even upto now a fully authenticated list of the alternate host plants of this important insect pest is not known. Some work has been carried out in this direction and evidently much more remains to be done.

Cotton Jassid is a small and very active insect and probably wind plays a great part in its dispersal and the adults can be collected from a majority of the green plants. Consequently mere presence of adults on a plant is not at all a sure indication of its being a host plant

This has led to lot of confusion and a clear-cut definition of host plant is necessary It is therefore proposed that a plant may be called a host plant, only if the pest can actually *feed and breed* on it. In the present studies, therefore, the breeding of the pest on different plants, suspected to be its hosts, was studied

METHOD OF STUDY

In order to find out the range of host plants of cotton jassid, its oviposition and nymphal development was studied on the following 18 plants :—

'Kadu' (*Lagenaria vulgaris*), 'kalitori' (*Luffa ægyptiaca*), 'tinda' (*Citrullus vulgaris*), 'halwa kadu' (*Cucurbita maxima*), tomato (*Solanum lycopersicum*), 'karela' (*Momordica charantia*), 'guara' (*Cyamopsis psoralioides*), grape vine (*Vitis vinifera*), 'falsa' (*Grewia asiatica*), hollyhock (*Althea rosea*), zinnia (*Zinnia* sp), sunflower (*Helianthus annus*), 'gul dhatura' (*Datura fastuosa*), 'bhindi' (*Hibiscus esculentus*), 'gurhal' (*Hibiscus rosasinensis*), changeable rose (*Hibiscus mutabilis*), *Hibiscus tiliaceus*, and 'ban kapas' (*Hibiscus vitifolius*).

(*a*) *Oviposition on different plants*—To study the comparative oviposition, leaves of these plants were enclosed in voil cloth sleeves about a week before the actual liberation of adults, to avoid promiscuous oviposition. At the time of liberation of adults the leaves were thoroughly examined and all the nymphs present on these were killed and removed. Some 25 adults collected from bhindi fields were introduced in each sleeve and 3 such sleeves were put up on each plant at each observation. The experiment was repeated once a week during the months of June and July, 1943. Oviposition was studied indirectly by counting the number of nymphs that hatched out on each plant. During the course of these observations oviposition by some 350 or more adults was studied on each plant, (*b*) *Nymphal development.*—These studies were carried out side by side with the oviposition studies and the method followed was also the same. In this case 20 first instar nymphs collected from 'bhindi' were liberated in each sleeve and the adults formed from these recorded. In all, the development of about 300 nymphs were studied on each plant.

DISCUSSION OF DATA

The average number of eggs laid by 25 adults and the average number of adults formed from 20 nymphs are given in Table I.

TABLE I

Oviposition and nymphal development on different plants

No	Name of plant	No. of eggs laid by 25 adults	No. of adults formed from 20 nymphs
	'Kadu' (*Lagenaria vulgaris*)	0·36	0·00
	'Kalitori' (*Luffa aegyptiaca*)	2 57	0·00
	'Tinda' (*Citrullus vulgaris*)	0·06	0·00
	'Halva kadu' (*Cucurbita maxima*)	1·85	0·09
	Tomato (*Solanum lycopersicum*)	2·25	0 00
	'Karela' (*Momordica charantia*)	0·80	0·00
	'Guara' (*Cyamopsis psoralioides*)	0 60	0·07
	Grape vine (*Vitis vinifera*)	0 00	0·06
	'Falsa' (*Grewia asiatica*)	0·00	0·50
10	Hollyhock (*Althea rosea*)	4·63	4·75
11	Zinnia (*Zinnia* sp.)	0·00	0·00
12	Sunflower (*Helianthus annuus*)	1 47	1·67
13	'Gul dhatura' (*Datura fastuosa*)	0·25	0·75
14	'Bhindi' (*Hibiscus esculentus*)	66·67	17·00
15	'Gurhal' (*Hibiscus rosasinensis*)	2·05	0·00
16	Changeable rose (*Hibiscus mutabilis*)	4·67	1·07
17	*Hibiscus tiliaceus*	1·00	1·13
18	'Ban kapas' (*Hibiscus vitifolius*)	0·00	0·00

The observations given in Table I are very interesting and show that with regard to oviposition and nymphal development, these plants can be divided into the following four categories:—

(*a*) Those on which neither oviposition nor feeding could take place, such as 'tinda', grape-vine, zinnia and 'ban kapas'.

(*b*) Those on which the adults could not oviposit but the nymphs could feed such as 'falsa'

(*c*) Those on which the oviposition could take place but the insect could not feed, such as 'kadu', 'kalitori', 'halwa kadu', tomato, 'karela', 'guara' and 'gurhal'.

(*d*) Those on which both feeding and oviposition could take place, such as 'bhindi', hollyhock, sunflower, ***Hibiscus tiliaceus***, changeable rose and 'gul dhatura'

It is thus clear from the aforesaid that plants belonging to the first three categories could obviously not be considered alternate hosts of ***E. devastans*** while the plants enumerated in the fourth category were the only ones, amongst these 18 under trial, that are really the alternative food plants of this pest.

CONCLUSIONS

The list of alternate host plants of *E. devastans* given by Husain and Lal can now be revised in the light of present knowledge and is given below in order of the importance of the plant:—

1 *Hibiscus esculentus* (Bhindi)
2 *Althea rosea* (Hollyhock)
3 *Solanum melongena* (Brinjal)
4 *Solanum tuberosum* (Potato)
5 *Hibiscus mutabilis* (Changeable rose)
6 *Hibiscus tiliaceus*
7 *Helianthus annus* (Sunflower)
8 *Datura fastuosa* (Gul dhatura)

ACKNOWLEDGEMENT

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THE INHIBITORS OF ENZYMATIC AND CUPRIC ION OXIDATION OF VITAMIN C

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The oxidation of ascorbic acid and its retardation by various substances have been studied by several workers Noteworthy examples of substances which are found to inhibit the oxidation of ascorbic acid are glutathione and cysteine (De Caro and Giani, 1934; Bersin *et al*, 1935; Barron *et al.*, 1936; Ghosh and Rakshit, 1936; Hopkins and Morgan, 1936); metaphosphoric acid (Fujita and Iwatake, 1935, Levy, 1936; Hinsberg, 1937; Musulin and King, 1936), Pyrophosphate (Giri, 1937; Giri and Doctor, 1938; Krishnamurthy and Giri, 1941 *a*, Lugg, 1942); tannin from Indian Gooseberry (*Phyllanthus emblica*) (Damodaran and Nair, 1936); and oxalic acid (Krishnamurthy and Giri, 1941 *c*; Seshagiri Rao and Giri, 1942; Ponting, 1943) The importance of the discovery of such inhibitors of vitamin C oxidation lies in their application to the determination of vitamin C content of foodstuffs in order to prevent the oxidation of the vitamin during extraction, the preparation of stable aqueous solutions of the vitamin and in the study of the nature of catalytic systems present in plant and animal tissues which oxidise the vitamin

Among the inhibitors of vitamin C oxidation metaphosphoric acid has been widely used by various workers for extraction of the vitamin from plant and animal materials. Pyrophosphate which was found to stabilise the vitamin (Giri, 1937) has also been used by several workers for extraction and stabilisation of the vitamin (Mitra, *et al.*, 1940, Lugg, 1942; Klodt and Steib, 1938; Steinman and Dawson, 1942)

Some of the inhibitors of vitamin C oxidation which exert their effect on cupric ion oxidation without exerting any influence on the enzymic oxidation may be useful in eliminating the catalytic effect of copper while studying the enzymic oxidation of the vitamin Thus Krishnamurthy and Giri (1941 *a*) showed that pyrophosphate has no influence on the enzymic oxidation of vitamin C while it retards considerably the cupric ion oxidation of the vitamin This property of pyrophosphate was made use of in investigations on the mechanism of the ascorbic acid-ascorbic acid oxidase reaction by Steinman and Dawson (1942) Furthermore, Giri and Seshagiri Rao (1942) in a preliminary note have reported that some of the purine derivatives such as xanthine, uric acid, guanine, theophylline have the specific property of inhibiting only the cupric ion oxidation without exerting any influence on the enzymic oxidation of the vitamin Recently Snow and Zilva (1942) have utilised the property of these inhibitors in their studies on the nature of the catalytic system in tea infusions which catalyse the aerobic oxidation of ascorbic acid.

The foregoing findings together with the observation that the enzyme ascorbic acid oxidase is a copper protein compound (Stotz *et al*, 1937) suggested that a comparative study of the influence of inhibitors on copper oxidation and enzymic oxidation of the vitamin might be advisable In a previous note (Giri and Krishnamurthy, 1941; Krishnamurthy and Giri, 1941 *c*) it was shown that certain purine derivatives inhibit the oxidation of ascorbic acid by Cu and these results on the stabilising action of purines have been confirmed recently by other workers (*cf*, Bergel, 1944) The present paper deals with a more detailed study of these and other inhibitors of vitamin C oxidation.

EXPERIMENTAL

The oxidation of vitamin C was followed both by manometric and titrimetric methods. The manometric method consisted in measuring the oxygen uptake from solution of vitamin C shaken in air in Warburg manometers. The buffer and the catalyst Cu together with the substance whose influence on the oxidation is to be examined were placed in the main chamber of the vessel, vitamin C solution being kept in the side arm and dropped into the main vessel when temperature equilibrium was reached The readings were taken at definite intervals of time

The water used for the preparation of buffers and other solutions was twice distilled in a pyrex distillation apparatus

The vitamin used in the present investigation was B. D H ascorbic acid. All the substances used were of the highest grade of purity, either Merck's or Kahlbaum's pure products

The pH of all solutions used in testing their influence on the oxidation of the vitamin was always adjusted to the pH of the experimental solution (pH 7·2). Some of the purine derivatives which are difficultly soluble in water are dissolved first in minimum amount of alkali and diluted to the required strength. These solutions when added in such low concentrations as were used in the experiments, were found to have no significant influence on the pH of the solution. All the solutions were always freshly prepared for each experiment.

In Table I are presented the results obtained manometrically on the influence of the compounds under investigation on the oxidation of vitamin C by Cu

TABLE I

The influence of purines and other substances on the oxidation of vitamin C

(By manometric method)

The experimental cup contained 0·8 c c M/15 phosphate buffer (pH 7 2); 0 2 c.c. copper sulphate solution containing 0 71 γ Cu and 1 5 c c. of buffer containing the substance whose influence on the oxidation is to be determined The side arm contained 2 mg. ascorbic acid dissolved in 0·5 c c of water and the central chamber contained 0 2 c c. of 20 per cent. KOH and filter paper The vessels were placed in the manometers with the stopcocks open and introduced into the bath, which was accurately controlled (± 0 01 C) at the desired temperature 30° C, and the flasks equilibrated for five minutes. The stopcocks were then closed the vitamin C solution dropped into the main vessel and the readings were taken at definite intervals of time

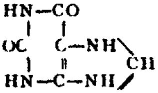
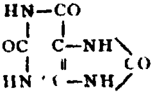
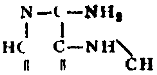
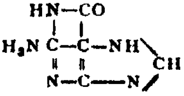
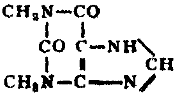
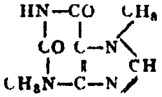
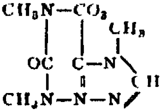
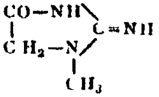
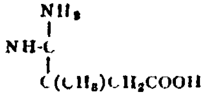
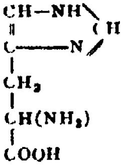
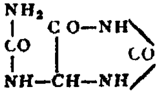
	Substance added	Formula	Concentration 10^{-4}(M)	μl O_2 uptake time in minutes					
				5	10	15	20	25	30
Ascorbic acid + Cu	..	..	..	17	43	69	95	114	132
Do	xanthine		1·7 8·5	0 0	0 0	0 0	0 0	0 0	0 0
Do	uric acid		1·5 7·5	0 0	0 0	0 0	0 0	0 0	0 0
Do	adenine		1·6 8·0	0 0	0 0	0 0	0 0	0 0	0 0
Do	guanine		1·7 8 5	0 0	0 0	0 0	0 0	0 0	0 0
Do	theophylline		1·4 7·0	6 0	9 0	12 0	.. 0	.. 0	17 0

TABLE I—*Contd*

	Substance added	Formula	Concentration 10^{-4}(M)	µl O_2 uptake time in minutes					
				5	10	15	20	25	30
Do	theobromine		7·0	10	40	65	85	103	120
Do	caffeine		6·4	10	35	62	80	101	126
Do	yeast nucleic acid	$C_{26}H_{42}N_{14}P_{3}O_{31}$	0·0025% 0·0125%	0 0	0 0	0 0	0 0	0 0	0 0
Do	creatinine (2,3-dihydro-2-imino-1-methyl-4(5) imidazolone]		2·2 * 11·0	8	22 2	35 5	50 7	62 9	77 10
Ascorbic acid +Cu	creatine	 $NH{-}\overset{NH_2}{\underset{C(CH_3)CH_2COOH}{C}}$	9·5	15	40	62	88	106	130
Do	histidine (a amino β imidazolyl propionic acid or β imidazolyl alanine		1·8	..	10	25		.	58
Do	allantoin		1·76 7·8	. ..	21 4	36 8	52 12	67 15	84 19

The results indicate that the purine derivatives xanthine, adenine, guanine, uric acid, theophylline and yeast nucleic acid completely inhibit the oxidation of the vitamin, while theobromone and caffeine have no significant influence on the oxidation at pH 7·2 and in the concentrations used in the experiments. Creatinine is found to inhibit the oxidation, while creatine is without effect on the reaction. Histidine and allantoin also inhibit the oxidation

With a view to confirming the results obtained manometrically the rate of oxidation of the vitamin in presence and absence of the substances was followed by estimating the vitamin by the usual titration method. For purposes of comparison the well-known inhibitors sodium diethyldithiocarbamate and 8-hydroxyquinoline were also included.

The results are presented in Table II.

The results confirm the observations made by manometric method.

TABLE II

The influence of purines and other substances on the oxidation of Vitamin C

(By titration method)

The reaction mixtures contained 10 c.c. of phosphate buffer M/15 (pH 7·2), 2 c.c. of ascorbic acid solution containing 5 mg of the vitamin, 3 c.c. of $CUSO_4\,5H_2O$ solution containing 10·7 γ Cu^{++} and 5 c.c. water or the solution containing the substance. The systems were let in open conical flasks of 100 c.c. capacity at a temperature of 35° C. in a thermostat. At the beginning of the experiments and thereafter at short intervals, 5 c.c. aliquots of the reaction mixture were taken and after acidification with glacical acetic acid, the vitamin content was determined by titration.

	Substance added	Concentration M	Mg. vitamin C after		
			0	30	60 min.
Ascorbic acid + Cu	..		5·0	2·2	0·73
Do	xanthine	3·3 10^{-4}	5·0	5·0	5·0
Do	uric acid	3·0 10^{-4}	5·0	5·0	5·0
Do	adenine	1·85 10^{-3}	5·0	5·0	5·0
Do	guanine	3·3 10^{-4}	5·0	5·0	5·0
Do	theophylline	2·8 10^{-4}	5·0	5·0	5·0
Do	yeast nucleic acid	0·005%	5·0	5·0	5·0
Do	creatinine	1·8 10^{-4}	5·0	4·5	4·0
Do	histidine	1·2 10^{-3}	5·0	4·7	4·0
Do	allantoin	3·1 10^{-3}	5·0	4·7	3·7
Do	Sodium diethyl dithio carbamate	1·79 10^{-3}	5·0	5·0	5·0
Do	8-hydroxyquinoline	1·72 10^{-3}	5·0	4·0	3·0

The results show that all the purine derivatives inhibit the oxidation of the vitamin in the absence of added Cu at pH 7·2. It is interesting to note from Table III that oxalic acid and 8-hydroxyquinoline which protect

TABLE III

The influence of purines and other substances on the oxidation of vitamin C at pH 7 2 in the absence of added Cu

The reaction mixture contained 10 c c. M/15 phosphate buffer (pH 7 2). 5 c c ascorbic acid solution containing 5 mg of the vitamin and 5 c c of water or the solution containing the substance under investigation The total volume of the reaction mixture was made up to 20 c.c The results are presented in Table III

	Substance added	Concentration M	Mg of vitamin C after incubation for		
			0 hr	24 hrs	48 hrs
Vitamin C	..	..	5·0	0	0
Do	xanthine	1·64 10^{-3}	5·0	3·6	3·1
Do	uric acid	1 49 10^{-3}	5·0	3·6	3·1
Do	adenine	1 85 10^{-3}	5·0	3·6	3·1
Do	guanine	1 65 10^{-3}	5·0	3·6	3·1
Do	theophiline	1 39 10^{-3}	5·0	2·0	2·2
Do	8 hydroxy quinoline	1·72 10^{-3}	5·0	0	0
Do	sodium diethyl dithio carbamate	1 79 10^{-3}	5·0	3·6	..
Do	Oxalic acid	1·98 10^{-3}	5·0	0	0

the vitamin at acid pH (Table IV) do not exert any protection against oxidation of the vitamin at the alkaline pH 7 2.

The influence of the inhibitors of cupric ion oxidation of vitamin C on the enzymic oxidation of the vitamin.—The observation that the enzyme ascorbic acid oxidase is a copper-protein compound (Stotz *et al*, 1937) suggested that a comparative study of the influence of the inhibitors on Cu oxidation and enzymic oxidation of the vitamin might be useful in throwing light on the nature of the Cu-protein linkage.

For the enzymic oxidation the enzyme ascorbic acid oxidase was prepared from pumpkin (*Cucurbita maxima*) and snake gourd (*Tricosanthus anguina*) (Krishnamurthy and Giri, 1941 *b*) The enzyme was prepared by extracting the finely minced vegetable with 30 per cent. alcohol and dialysing the extract for about 16 hours in collodion bags

The amount of the enzyme solution used for the experiments was so adjusted that the rates of oxidation of the vitamin by the enzyme and Cu were practically the same. The results are presented in Table IV.

TABLE IV

The influence of the inhibitors of Cu-oxidation of vitamin C on the enzymic oxidation of the vitamin

The reaction mixture consisted of 10 c.c. M/5 acetate buffer (pH 5·6), 5 c.c. vitamin C solution containing 5 mg. V. C.), $CuSO_4 \cdot 5H_2O$ solution containing 8·02 γ Cu^{++} + (for Cu-oxidation) or enzyme solution (for enzymic oxidation) and the solution of the inhibitor, the total volume being adjusted to 20 c.c. Incubation temperature, 35° ± 0·1° C.

Substance	Concentration of the substance	mg. of Vitamin C found in reaction mixtures containing								
		Vitamin C + Cu^{++}			Vitamin C + ascorbic acid oxidase (from pumpkin)			Vitamin C + ascorbic acid oxidase (from snake gourd)		
		0 min	30 min	60 min	0 min	30 min	60 min	0 min	30 min	60 min.
Nil	.	5	2·8	1·6	5	3·0	2·0	5	2·8	1·7
Sod. diethyl dithiocarbamate	1·70 × 10^{-3} M	5	5	5	5	5	5	5	5	5
8 Hydroxyquinoline	1·72 × 10^{-3} M	5	5	5	5	5	4·9	5	4·4	4·4
Adenine	1·85 × 10^{-3} M	5	4·9	4·6	5	3·0	2·0	5	2·8	1·6
Uric acid	1·49 × 10^{-3} M	5	4·9	4·6	5	3·0	1·8	5	2·9	1·7
Guanine ..	1·65 × 10^{-3} M	5	4·9	4·9	5	3·0	1·8	5	2·9	1·6
Xanthine .	1·64 × 10^{-3} M	5	4·9	4·9	5	3·0	1·9	5	2·8	1·7
Theophylline .	1·30 × 10^{-3} M	5	4·7	4·6	5	3·0	1·8	5	2·8	1·7
Creatinine ..	2·21 × 10^{-3} M	5	4·6	4·2	5	3·0	1·9	5	2·9	1·7
Oxalic acid .	1·98 × 10^{-3} M	5	4·7	4·2	5	3·0	2·0	5	2·0	1·8

The results show that sodium-diethyl-dithiocarbamate and 8-hydroxyquinoline inhibit both the Cu and enzymic oxidation of vitamin C, while the purine compounds, creatinine and oxalic acid, inhibit only the Cu oxidation of the vitamin without any inhibiting action on the enzymic oxidation of the vitamin.

The specific inhibiting action of purines and other substances on the Cu oxidation of vitamin C in presence of the enzyme ascorbic acid oxidase.—The specific property of some of the inhibitors in inhibiting the Cu oxidation of the vitamin without exerting any influence on the enzymic oxidation of the vitamin, may be useful in studying the nature of the catalytic systems present in plants which oxidise the vitamin. The inhibitors can be used for preventing the action of Cu on the vitamin when investigating the nature and action of the enzyme ascorbic acid oxidase on vitamin C. In view of the importance of such inhibitors in their application to the study of the nature of catalytic systems for the oxidation of the vitamin, experiments were carried out on the influence of the inhibitors on the Cu oxidation of the vitamin in presence of the enzyme ascorbic acid oxidase.

The results of these experiments are presented in Table V.

TABLE V

The inhibiting action of purines and other compounds on the Cu oxidation of Vitamin C in presence of the enzyme ascorbic acid oxidase

The reaction mixture consisted of 10 c.c. M/5 acetate buffer (pH 5.6), 5 c.c. vitamin C solution, containing 5 mg., 1 c.c. of the enzyme (from snake gourd), 0.75 c.c. of $CuSO_4.5H_2O$ containing 8.2 γ Cu and 3.25 c.c. water or the solution of the substance whose influence on the oxidation of the vitamin is to be investigated. Temperature, 35 ± 0.1 C

Reaction mixture	Inhibitor	Concentration of inhibitor M	Mg. of vitamin C		
			0 min.	30 min.	60 min.
Vitamin C + enzyme	.	.	5.0	2.9	1.7
Vitamin C + enzyme + Cu	.		5.0	2.3	1.1
Vitamin C + enzyme + Cu	oxalic acid	1.98×10^{-3}	5.0	3.1	1.0
Vitamin C + enzyme + Cu	adenine	1.85×10^{-3}	5.0	2.85	1.7
Vitamin C + enzyme + Cu	uric acid	1.49×10^{-4}	5.0	2.9	1.9
Vitamin C + enzyme + Cu	creatinine	1.21×10^{-3}	5.0	2.9	1.3

The above results clearly indicate that the substances investigated annul the inhibition of vitamin C oxidation by Cu in presence of the enzyme as ascorbic acid oxidase, the enzymic oxidation being unaffected as before.

DISCUSSION

From the observations reported it is evident that the oxidation of vitamin C by Cu is completely inhibited by xanthine, adenine, guanine, uric acid, theophylline and yeast nucleic acid, while caffeine and theobromine have no influence on the oxidation under the experimental conditions described. In order to determine which portion of the purine derivatives is responsible for the observed effect, the influence of other compounds having the iminazole group have been tested and the results of these tests can be summarised as follows:

1. The iminazole component is esssential for the inhibiting action of the purine derivatives and other iminazole compounds investigated. This is supported by the following observations:

(*a*) In addition to the purine derivatives, creatinine (2, 3-dihydro-2-imino-1-methyl-4-(5)-imidazolone), histidine (β-imodazolylalanine) and allantoin, which contain the iminazole component, exert inhibiting action on the oxidation, although the extent of inhibition is not so great as that with the purine derivatives, under similar experimental conditions.

(*b*) The inhibiting action is destroyed by the breakdown of the iminazole ring structure. Thus creatinine, which contains the iminazole ring, exerts inhibition, while creatine which is formed from creatinine by breaking the ring structure, does not exert similar action on the oxidation of the vitamin.

2 The imino group of the purine derivatives appear to be directly concerned with the inhibitory action of these compounds as the replacement of the hydrogen atoms of the imino groups causes loss of the inhibitory property Thus the purine derivatives, xanthine, adenine, guanine and uric acid whose imino groups are free, exert considerable inhibition, while caffeine whose imino groups are completely methylated has no such inhibiting action The inhibiting property of the purine compounds tested depends, therefore, upon the presence of free imino groups in the molecule

3 Among the imino groups of the purine derivatives, the imino group 7 appears to exert a decisive influence on the oxidation of the vitamin, since the replacement of the hydrogen atom of the imino group by methyl group causes a complete loss of the inhibitory property, although the other imino groups are free Thus while theophylline which contains free 7 imino group acts as inhibitor, theobromine with its 7 imino group methylated does not affect the oxidation. The evidence on the whole appears in favour of the view that the inhibiting action of the purine derivatives is due to the free 7-imino group of the purines

The mechanism of inhibition—As to the mechanism of inhibition of vitamin C oxidation, it is conceivable that the inhibitor forms a complex with copper, thereby preventing the action between the metal and the substrate as in the case of glutathione (Hopkins and Morgan, 1936). The complex thus formed is probably of such a type that transformation of Cu^{1} to Cu^{11}, or the reverse is not possible This transformation is necessary for the Cu to exert its catalytic effect on the vitamin. Copper combined with the substance, which functions as inhibitor, may not retain its catalytic properties, as in the ionic state

The results are of interest in indicating the existence of substances in tissues other than glutathione, which exert powerful protection against the oxidation of vitamin C The fact that purine derivatives, nucleic acids and creatinine are widely distributed in the biological kingdom lends biological significance to these results and points to the possibility that the deleterious effects of Cu which is widely distributed in all living cells together with the vitamin, are diminished or completely eliminated by such substances. An attempt is being made to study further the reactions involved, with a view to the elucidation of the mechanisms concerned in the retardation of the oxidation by the substances investigated.

Classification of the inhibitors of vitamin C oxidation —We have also observed (Table IV) that some of the substances when used in concentrations at which they inhibited completely the oxidation of the vitamin by copper, are ineffective on the enzymic oxidation of the vitamin, a point of interest indicating the difference between the enzymic and Cu-oxidation. Sodium diethyldithio carbamate and 8-hydroxiquinolin, however, inhibit both the enzymic and cupric ion oxidation of the vitamin. The various inhibitors of vitamin C oxidation so far known from literature are listed and classified in Table VI according to the effects they produce on the enzymic, cupric ion and other types of oxidation of the vitamin.

The inhibitors may be classified into two main categories: (1) Inhibitors like oxalic acid and purine derivatives which inhibit the oxidation of the vitamin by Cu without exerting any influence on the enzymic oxidation and (2) Inhibitors like sodium diethyl dithio carbamate and 8-hydroxyquinolin which inhibit both the enzymic and cupric ion oxidations

One of the special advantages of the specific property of the inhibitors belonging to the first category in preferentially retarding the Cu oxidation of the vitamin, is that in their presence the effect of Cu can be eliminated while studying the action of other catalytic systems such as the enzyme ascorbic acid oxidase on the vitamin Thus pyrophosphate which was shown by Krishnamurthy and Giri (1941 *a*) to inhibit the Cu oxidation of ascorbic acid without exerting any influence on the enzymic oxidation has been used by Steinman and Dawson (1942) in their studies on ascorbic acid-ascorbic acid oxidase reaction in order to prevent the action of Cu in the reaction mixture Similarly Seshagiri Rao and Giri (1942) have used the inhibitors (oxalic acid) for eliminating the influence of Cu in the reaction mixture on ascorbic acid in their studies on the influences of ascorbic acid on amylase The rapid oxidation of ascorbic acid in certain plant press juices and vegetables when exposed to air may be due to the catalytic effect of Cu or enzymes. In such cases these inhibitors which preferentially retard the Cu oxidation of the vitamin may prove to be very useful tools in the study of the nature of the catalytic systems in plants which oxidize vitamin C; for any oxidising system containing free ionised copper can be detected by the inhibition produced on adding any one of the above inhibitors to the system.

TABLE VI

Inhibitors of Vitamin C oxidation

I Inhibition ; O No effect on the oxidation

Substance	Auto-oxidation	Oxidation by Cu	Enzymic oxidation	Oxidation by other systems	Reference
I Organic compounds					
1 Thiol-and disulphide compounds—					
Glutathione	I	I	I	.	Hopkins and Morgan (1936), Bersin *et al* (1935), Mawson (1935)
do		I	0	.	Barron *et al* (1936a)
do	I		.		Ghosh and Rakshit (1936)
do		.	.	Photo oxidation I	Hopkins (1938), Arcus and Zilva (1940)
Cysteine	I	I	.		Barron *et al* (1936b)
do	..			Oxidation by tea infusion I	Snow and Zilva (1942)
Cystine	I	.			Rudolph (1938); Mawson (1935)
Sodium and		I	I	.	Stotz *et al* (1937)
hydrogen sulphide		I			Seshagiri Rao and Giri (1942), Mawson (1935)
Potassium thiocyanate	..	I	I		Stotz *et al* (1937)
thiourea		I	I (reversible)	..	McCarthy *et al* (1939), Kawerean and Fearon (1940)
2. Proteins and amino acids—					
Proteins and amino acids	..	I	0		Barron *et al* (1936)
Casein and edestin	I			..	Bergel (1944)
Egg albumin	.	I		.	Krishnamurthy and Giri (1941*c*)
do	..	.	.	Oxidation by tea infusion I	Snow and Zilva (1942)
Dried ovalbumin	I				Rudolph (1938)
Peptone	.	I		..	Krishnamurthy and Giri (1941*c*)
Glycine		I	0		Stotz (1940)
do		0 (PH 6 6)	.	..	Mcfarlane (1936)
do	.	..		Oxidation by tea infusion 0	Snow and Zilva (1942)
do	I	.	.		Mystkowski and Losocka (1939)
Leucine and aspartic acid	I	—	..	..	Mystkowski and Lasocka (1939)
Phenylalanine	I	..		..	Rudolph (1938)
Histidine	..	I	.	..	Seshagiri Rao and Giri (this paper)
3 Purine compounds					
Adenine	I (PH 7 2)	I	0	..	Giri and Krishnamurthy (1941) Seshagiri Rao and Giri (this paper)
Xanthine	I (do)	I	0	..	*Idem* ; Bergel (1944)
Uric acid	I (do)	I	0	..	*Idem* ; Bergel (1944)
Guanine	I (do)	I	0	..	*Idem*
Theophylline	I (do)	I	0	..	*Idem*
Yeast nucleic acid	..	I		..	*Idem*
Sodium urate	..	I	..	Oxidation by tea infusion	Snow and Zilva (1942)

TABLE VI (*Continued*)

Substance	Auto-oxidation	Oxidation by Cu	Enzymic oxidation	Oxidation by other systems	Reference
I. Other compounds—					
Sodium diethyl dithiocarbamate	I	I	I	..	Stotz *et al* (1937) Seshagiri Rao and Giri
do	..	I	I (reversible)	..	McCarthy *et al* (1939)
do	.		..	Oxidation by tea infusion 0	Snow and Zilva (1942)
8-Hydroxy-quinolin	I (PH 7 2)	I	I	..	Seshagiri Rao and Giri (this paper)
do	..	I	I	..	Stotz *et al* (1937)
do	..	..	0		Barron *et al* (1936*b*)
Potassium ethyl xanthate	.	I	I	.	Stotz *et al.* (1937) McCarthy *et al* (1939)
Creatinine	.	I	.	.	Giri and Krishnamurthy (1941)
Salicyldioxime	.	I	I	.	McCarthy *et al* (1939)
l-adrenalin	I (pH 7 4)	.	..	..	Yamamoto (1936)
Allantoin	..	I	..	.	Seshagiri Rao and Giri (this paper)
Pyridine	..	I	I	..	Stotz *et al* (1937)
Protoporphyrin	0	I	.	..	Schreus and Schummer (1940)
Oxalic acid	I (pH 6·0) 0 (pH 7 2)	I	0	.	Krishnamurthy and Giri (1941*c*), Seshagiri Rao and Giri (this paper) Ponting (1943)
Citric and tartaric acids	.	I	..	..	Krishnamurthy and Giri (1941*c*)
Chlorophyll	I	.	.		Rakshit (1938)
Lecithin (egg)		I .	.	.	Krishnamurthy and Giri 1941*c*)
Acqueous extracts of animal tissues liver, kidney, muscle, spleen, intestines, and erythrocytes	I	I	.	.	Kellie and Zilva (1935), Mawson (1935) De Caro and Giani (1934*c*) Giri and Shourie (1939), Schreus and Schummer (1940)
Leucocytes	0	0	.		Kellie and Zilva (1935)
II. Inorganic compounds					
Metaphosphoric acid	I	I	..		Fujita and Iwatake (1935) Musulin and King (1936) Hinsberg (1937)
Pyrophosphate	I	I			Giri (1937), Giri and Doctor (1938), Krishnmurthy and Giri (1941*a*), Steinman and Dawson (1942)
Sodium chloride	I	I		.	Decaro and Giani (1934), Kellie and Zilva (1935) Mystkowaski and Lasocka(1939), Mapson (1941)
do	.	..	0	.	Mystkowaski (1942)
Potassium ferrocyanide	..	I	I	.	Stotz *et al.* (1937)
Sodium azide	..	I	I		McCarthy *et al.* (1939)
Boric acid	..	..	..	Oxidation by tea infusion I	Snow and Zilva (1943)
Hydrogen-cyanide	..	I	I	..	Hopkins and Morgan (1936), Stotz *et al.* (1937) McCarthy *et al.* (1939)

The inhibitors of the enzymic oxidation of ascorbic acid.—Stotz *et al.* (1937) examined the influence of a number of compounds which inhibit the catalytic oxidation of ascorbic acid by Cu on the enzyme ascorbic acid oxidase. They found that sodium diethyldithiocarbamate, 8-hydroxyquinolin, pyridine, potassium thiocyanate, sodium cyanide, potassium ethyl xanthate, potassium ferrocyanide and sodium sulphide which acted as copper inhibitors produced nearly complete poisoning of the enzyme as well as inorganic copper and copper-protein mixture. On the basis of these results the authors suggest that ascorbic acid oxidase is a copper-protein compound and that the activity of ascorbic acid oxidase is related to the presence of copper in combination with proteins On the other hand, Barron *et al.* (1936 *b*) found that glutathione, proteins and aminoacids protected ascorbic acid from oxidation through the agency of catalytic metals such as Cu, but not from oxidation by enzymes such as the ascorbic acid oxidase of squash. Later Krishnamurthy and Giri (1941 *a*) found that pyrophosphate which inhibits the Cu oxidation of ascorbic acid does not exert any significant influence on the enzymic oxidation of the vitamin. Mystkowski (1942) has shown that the oxidation of ascorbic acid by Cu is inhibited by NaCl, while the activity of ascorbic acid oxidase from cucumber is not influenced by it. The results reported in the present investigation also show that except 8-hydroxyquinolin and sodium diethyldithiocarbamate all the compounds investigated, namely adenine, uric acid, guanine, xanthine, theophylline, creatinine and oxalic acid do not exert any inhibition on the enzymic oxidation of ascorbic acid, while the Cu oxidation of the vitamin is considerably inhibited in their presence It is clear therefore that all substances which inhibit the Cu oxidation of the vitamin need not necessarily inhibit the enzymic oxidation Our present knowledge of the chemical nature of the enzyme ascorbic acid oxidase is too limited to allow a fundamental approach to the interpretation of the nature of the difference observed on the effect of the inhibitors on the enzymic and Cu oxidation of the vitamin, but nevertheless it offers interesting field for further exploration.

SUMMARY

1 The influence of xanthine, adenine, uric acid, theophylline, guanine, creatinine, oxalic acid, sodium diethyldithiocarbamate and 8-Hydroxyquinolin on the oxidation of vitamin C by Cu and ascorbic acid oxidase has been studied.

2. Sodium diethyldithiocarbamate and 8-hydroxyquinolin inhibit both the enzymic and Cu oxidation of vitamin C. The other compounds investigated inhibit only the Cu oxidation without exerting any influence on the enzymic oxidation of the vitamin.

3. The bearing of these results on the nature of ascorbic acid oxidase and their application to the study of the nature of catalytic systems in plants which oxidise the vitamin have been discussed Various types of inhibitors of vitamin C oxidation have been listed and properly classified.

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